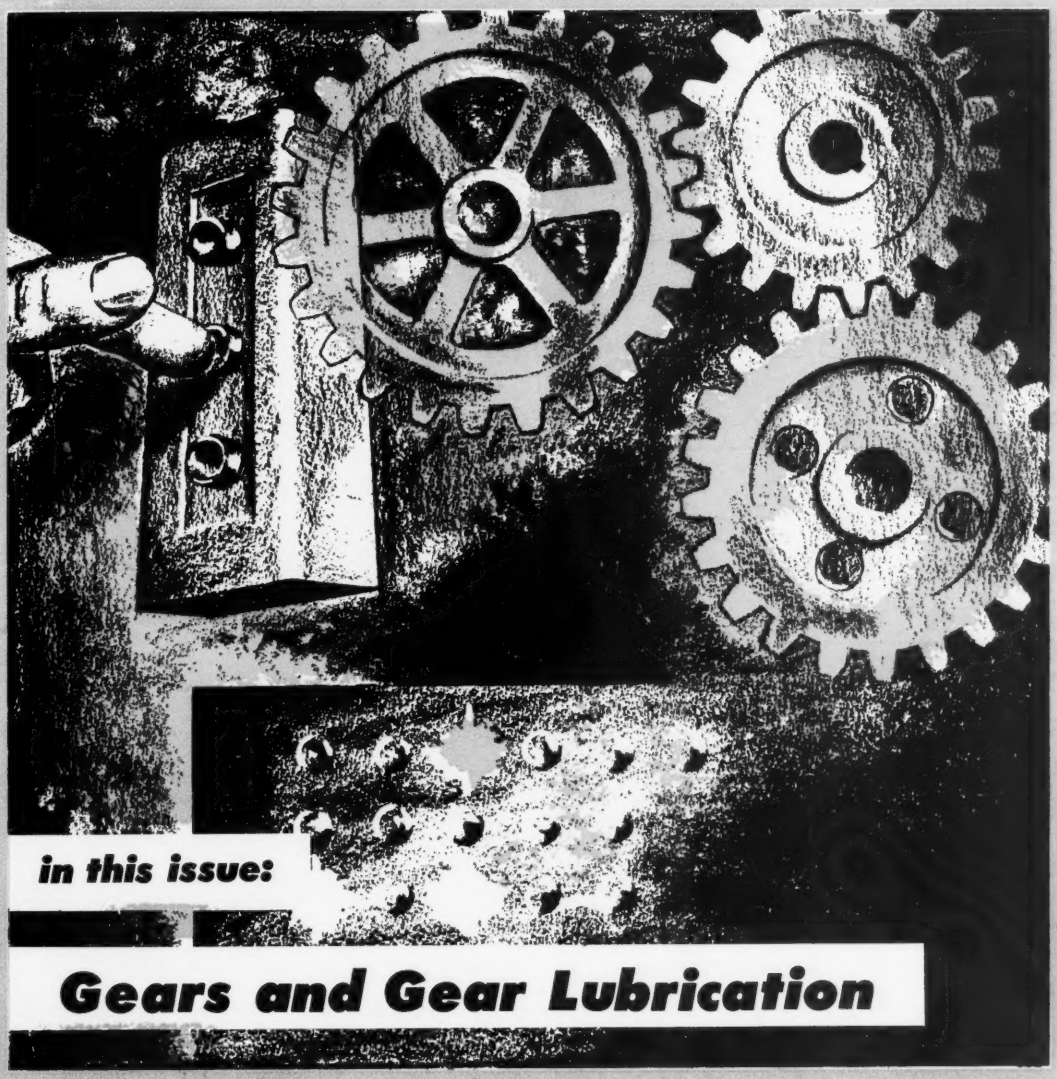
Vol. 15, No. 9 September, 1959

LUBRICATION ENGINEERING

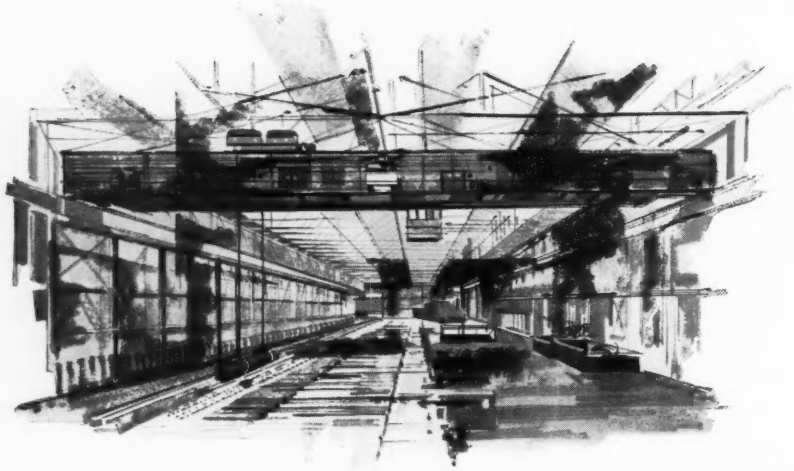
DESIGN RESEARCH APPLICATION EDUCATION MAINTENANCE



in this issue:

Gears and Gear Lubrication

JOURNAL OF THE AMERICAN SOCIETY OF LUBRICATION ENGINEERS



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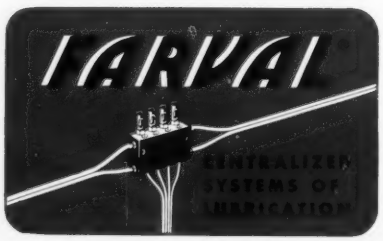

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Volume 15, No. 9
September, 1959

Lubrication Engineering

DESIGN RESEARCH APPLICATION EDUCATION MAINTENANCE

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ASTM to Have Technical Program

Another record for technical programs of the American Society for Testing Materials will be established at San Francisco, October 11-16, 1959, when the Society will convene for its 3d Pacific Area National Meeting with headquarters at the Sheraton-Palace. Three years of planning with more than a year of intensive work by the committees concerned will be culminated in an outstanding program of 53 technical sessions, five industry luncheons, an exhibit of instruments and apparatus, a group of educational visits to industrial laboratories and plants, and an extensive ladies' entertainment program. To adequately house the visitors and members and to provide appropriate meeting room accommodations, the Saint Francis, Drake-Wilshire, Sir Francis Drake, Sutter, and other hotels will be used. Some sessions will be held also at the Pacific Gas and Electric Company Auditorium.

The five industry luncheons are: Petroleum and Chemicals, Electronics, Statistics, Industrial Water, and Cement and Concrete.

Symposiums and forums are scheduled on the following subjects: Nuclear Problems, Masonry Materials, Ceramics in Nuclear Energy, Nondestructive Testing in the Missile Industry, Electrical Insulating Materials, Technical Development in the Handling and Utilization of Water and Industrial Waste Water, Spectroscopy, Methods for Testing Building Constructions, Applied Radiation and Radioisotope Test Methods, Durability and Weathering of Structural Sandwich Constructions, Hydraulic Fluids, Materials in the Electronics Industry, Treated Wood for Marine Use, Effect of Water-Reducing Admixtures on Properties of Concrete, Radiation Effects and Dosimetry, Wood in Building Construction, Fatigue of Aircraft Structures, Reinforced Plastics, Thermal Ablation, Road and Paving Materials, Newer Metals, Bituminous Waterproofing and Roofing Materials, Soils for Engineering Purposes, Air Pollution Control, Post Irradiation Effects in Polymers, Standards—Are Changes in Order?, and Paint.

Preprints of papers and reports will not be available prior to the meeting. Most of the papers will be available in mimeographed form at the meeting at 50 cents a copy. Subsequent to the meeting, it is planned that most of the papers will be published as Special Technical Publications of the Society as rapidly as the editorial work and printing can be completed.

Steel Engineers To Hold Convention

The 1959 annual convention of the Association of Iron and Steel Engineers will be held September 28, 29, 30 and October 1 at the Hotel Sherman, Chicago, Illinois.

A total of 36 papers will be presented, covering such timely and significant items as: blowing methods in steelmaking; feedback automatic gage control for hot strip mills; automatic programming control for rolling mills; application of the mercury arc rectifier to large reversing mill drives; the basic open hearth roof; and continuous annealing line drive systems.

The formal banquet will be held on Wednesday, September 30.

An inspection trip to Inland Steel Co.'s Indiana Harbor Works is also scheduled.

The meeting is open to all members of the iron and steel and allied industries.

Grease Production Figures Available

More than a billion pounds of lubricants were produced in the United States and Canada in 1958. A survey with 84 per cent return on production figures of lubricating greases and fluid gear lubricants was announced by the National Lubricating Grease Institute.

This was NLGI's second survey and the figures showed a slight loss in total 1958 production because of the recession, but some gains in different types of thickeners were noted. A larger fluid gear lubricant total was also given in the two-year comparison figures.

For ten dollars, copies of the 1958 Production Survey may be purchased from NLGI, 4638 J. C. Nichols Parkway, Kansas City 12, Mo.

Air Used to Brake

Air is being used as a lubricant to cushion and control the fast-whirling magnetic tapes on the Honeywell 800 computer system it was revealed.

Firm fingers of air pressures and vacuums have replaced mechanical brakes and clutches, traditionally used to guide the movement of data-bearing tape through the reading-writing mechanisms of computers, on the new transistorized computer now under construction at the Datamatic Division of Minneapolis-Honeywell, its designers announced.

"Our methods of applying air forces to handle the start-stop movement of tapes and to serve as a "lubricant" against touching other surfaces is an important solution to the 'handle with care' problem," Samuel D. Harper explained. "It will provide unprecedented reliability in tape operations, assuring gentleness and cleanliness by eliminating all metal contact with the data-bearing side of the tapes, except during the split-second intervals when the read-and-write head is in communication with the data."

It is reported that the new system will virtually eliminate tape damage resulting from internally created dust particles. Microscopic specks of magnetic oxide from the working surfaces and mylar dust from the opposite side formerly were worn off tapes by friction from capstans and pinch brakes. When these clumps of dust occasionally became embedded in the working surfaces they plagued the industry by affecting tape fidelity.

Honeywell's pneumatic techniques are said to reduce tape wear and slippage by distributing braking and clutching forces over areas ten times as great as those subjected to mechanical pinching, and add blowing and sucking actions to tape surfaces at the instant of releasing or applying force, thus contributing a cleansing factor.

The 2400-foot-long magnetic tapes in the system flash under the read-and-write head, which manipulates 3600 binary digits of information per inch, at a rate of 120 inches each second a data is "read" or "written" in computer language. Dust particles obliterating or garbling the data have been, in the past, a principal source of magnetic tape errors.

Survey Shows Rise In Engineers Income

Median income for professional engineers rose to a record high of $10,000 in 1958.

The figure is based on an analysis of 19,240 questionnaires returned by National Society of Professional Engineers members for the fourth biennial "Professional Engineers' Income and Salary Survey" published by the National Society.

One of the features of the 1958 report is a detailed analysis of salary trends recorded in the four surveys conducted since 1952.

Here are some of the major trends reported in the new survey:

All segments of the profession enjoyed further income gains between 1956 and 1958, but engineers connected with the business sector experienced smaller relative gains than those in other types of employment.

While the younger engineers continued to register salary increases, their gains were in line with those of the more experienced engineers, and not considerably

higher, as was the case in the past.

There appears to be a continuing trend —already apparent in 1956—toward a gradual lessening of certain types of income differentials. In particular, regional salary differentials seem to be decreasing, and there also seems to be a tendency for the various fields of employment to pay similar salaries for comparable work.

Copies of the 1958 Survey may be obtained from NSPE headquarters, 2029 K Street, N.W., Washington 6, D. C. The price is $1 for NSPE members and $2 for nonmembers.

Company Expands

Oronite Chemical Company announced a major expansion and reorganization of its development activities, including the creation of a Commercial Development Department.

The new department will encompass both market development and market research, according to T. G. Hughes, president. The company produces a broad range of petrochemical products.

Dr. R. I. Stirton was named general manager of the Commercial Development Department. Other appointments announced include Dr. W. E. Elwell as manager, market development; K. J. Van Arnum as manager, market research and R. E. Echols as supervisor, market development.

"Since the name Product Development is not truly descriptive of the expanding commercial development activities of the company, it was decided to realign those activities under a more suitable departmental name," Hughes said. He pointed out that the new department will have two primary functions.

"One function will be the commercial development of chemical products emanating from the research activities of California Research Corporation. A second and equally important function will be that of market research. This research will be applied in the interests both of new products being brought to commercial fruition by the market development group and of the company's products established in the industrial chemical field."

New Grease Patent

To clear up any misunderstanding, the Witco Chemical Company, Inc. advises that the last paragraph of the news release entitled "Patent Granted for New Grease" as reported in the "Lubrication in the News" section of the July LUBRICATION ENGINEERING should read as follows:

"Manufacturers purchasing the soap made with sebacic acid as one of the components from Witco or its licensees, according to Patent 2,699,428, may market the grease produced therefrom without the payment of royalties."

Soviet Research Reports Published

A collection of 107 translated Soviet research reports on the chemistry of the lanthanide and actinide elements has been published by Consultants Bureau, Inc., New York. The reports were selected by Gregory B. Choppin, Dept. of Chemistry, Florida State University, from 1949-1957 issues of the major chemical journals translated by the publisher.

All tabular material, graphs, and photograph material is reproduced, integral with the translations.

The collection "Soviet Research on the Lanthanide and Actinide Elements" (657 pages) is divided into the following five sections: Basic Chemistry (25 reports) $15.00; Analytical and Separation Chemistry (30 reports) $20.00; Nuclear Chemistry and Nuclear Properties (32 reports) $22.50; Geology (10 reports) $7.50; Nuclear Fuel Technology (9 reports) $7.50.

The sections may be purchased individually; the complete collection is priced at $65.00. A table of contents to the entire collection is available upon request to the publisher, Consultants Bureau, Inc., 227 West 17th St., New York 11, N. Y.

PERSONALS

William L. Rhodes has been appointed to the position of regional marketing analyst for the midwestern sales region of SKF Industries, Inc.

Kenneth B. Owings

Kenneth B. Owings has joined the research and development staff of the Briggs Filtration Company.

Sir Frederick Pickworth, chairman of the English Steel Corporation died July 14.

The Smoothies That Make Stainless Steel BEHAVE!
EN-AR-CO
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CUTTING OILS
H-2 SERIES
The finest cutting oils obtainable for the machining of stainless steel. The H-2 Series En-ar-co Promax Cutting Oils are specially compounded to overcome the difficulties encountered in machining stainless steel and to assure higher speeds, lower temperatures, longer tool life, better finish, and a sharp decrease in scrap.
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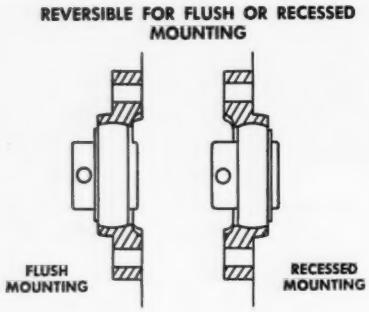
NEW PRODUCTS

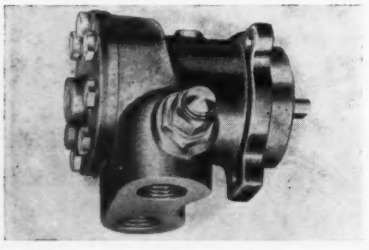
BEARING UNITS

Sealmaster Bearing Division of the Stephens-Adamson Mfg. Co., announces two new items; the LF three-bolt and LFT two-bolt flange bearing units in its precision, low-cost L type series line of ball bearing units. The regular L bearing cartridge with spherical O.D. is permanently mounted in the one piece malleable housing which provides maximum strength with light weight. Design of the housing permits either flush or recessed mountings for maximum application flexibility and desired shaft extension with minimum overhang. Housing also provides full housing contact under bearing ball path. Precision self-alignment takes place automatically between the spherical O.D. of the bearing and the spherical I.D. of the housing. Centrifugal-labyrinth seals retain the lubricant and prevent the entry of dirt. Effective and simple race to shaft lock is provided by two cup point set screws. The LF and LFT flanged units come pre-lubricated with high grade lubricant for long life and are completely assembled and ready for immediate service.



PUMP MINIMIZES LEAKAGE

The Tuthill Pump Company, 971 East 95th Street, recently announced the addition of new model LA pump to its line of 800 models. The pump particularly features a special spring loaded single lip seal. This new seal design was developed to provide the greatest possible protection against leakage when used with all lubricating and fuel oils and most hydraulic oils. The LA series is furnished in six different sizes with capacities to 6 gpm; for pressures to 500 psi; at 3600 rpm. It can be used in a wide variety of hydraulic, fuel oil, and lubricating applications.

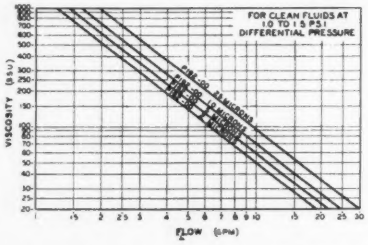


NEW MIST COOLANT UNIT ANNOUNCED

A new Mist Coolant System is announced by the Trico Fuse Mfg. Co. The Type "J" Trico-Mist is said to be especially designed for use on small machinery used for precision drilling, tapping, milling, sawing, grinding and other operations where space and low cost are factors. The units are supplied with dual valve controls—one to control air and the other the coolant supply. Coolant supply is always visible through a clear plastic reservoir which holds 8 oz. of coolant. A 2 ft. Neoprene coolant line terminates with a nozzle with a magnetic holder which simplifies nozzle positioning. Prices and further information may be obtained from the Trico Fuse Mfg. Co., 2948 N. 5th St., Milwaukee 12, Wisc.

FILTER SERIES HANDLE 1000 PSI

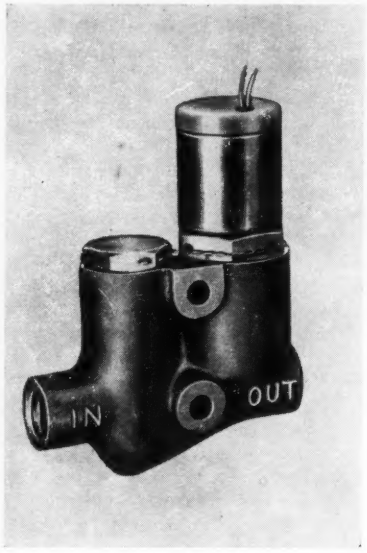
New high pressure filters capable of operating at pressures to 1000 psi and temperatures to 275F have been introduced. The filters—designated the P-192 series—are designed for use in pneumatic and hydraulic systems and are claimed to provide effective filtration for such fluids as lubricating oils, ethylene glycol mixtures, hydraulic fluids (including mineral oil base, silicate esters, and diester oil base), fuel, and oils, plus air and gases.



Any model in the series reportedly can be adapted for filtration of many other types of fluids by simply changing to the proper gasket material. Design versatility of the P-192 filter series permits use of replaceable paper elements, wire mesh, or varied-spacing metal-edge filtering media with degrees of filtration ranging from 2 to 25 microns. Clamp lock-ring construction on the steel housing affords easy element change and replacement without disconnecting the filter from the circuit. For further information about the P-192 series of high pressure filters for hydraulic and pneumatic circuits, write: Purolater Products, Inc., Rahway, N. J.

VALVE FEATURES LOW POWER CONSUMPTION

A new no-leak two way pilot operated solenoid valve for controlling the flow of hydraulic fluid MIL-0-5606 and similar liquids has been developed by Fluid Regulators Corp., Painesville, Ohio. The valve features low power consumption, fast positive response and low pressure drop. Of cartridge type construction, the continuous-duty solenoid may be quickly removed for easy maintenance. The valve operates on 0.185 amp, 25 volt D.C. Operating pressure is 3000 psi. Temperature range is —65F to +275F. Manufacturer's test specifications call for a proof pressure of 4500 psi, a burst pressure of 7000 psi, zero internal leakage and zero external leakage. The compact valve is only 4.53 inches high, 2.63 inches long and 1.25 inches wide. It weighs only 8 ounces. The solenoid may be furnished with leads or connector.



FORMABLE METALLIC PACKING

A new plastic metallic packing, suitable for high pressures and temperatures is now available for national distribution. Called Lonsor, the metallic substance is said never to deteriorate or harden; consequently it never needs to be replaced, only added to. It is packaged in one-lb cakes and is easily broken off and stuffed into the box, gland or shaft by hand. Being pliable, Lonsor conforms to the rod or shaft and makes a good bearing surface. Its inherent self-lubricating properties, derived from its antimony content,

(*Cont. on p. 346*)

Big Hit for Decca --DARINA

Decca Records, Pinckneyville, Illinois uses Shell Darina Grease 2 for the entire plant's grease lubrication.

When Decca Records opened their Pinckneyville plant late in 1957, they required a high-temperature grease for their hot plasticizing mills. After testing many greases under actual plant conditions, Shell Darina Grease 2 was selected. In fact, Darina® proved so successful in its original application that Decca now use it throughout the plant.

Darina Grease 2 is a premium-quality, multi-purpose grease with exceptional stability in extended high-temperature applications. It offers excellent resistance to corrosion and oxidation. It gives outstanding performance (compared with conventional soap-type greases) for long-time wet or dry applications at temperatures as high as 350° F.

For complete data on Darina Grease, write Shell Oil Company, 50 West 50th Street, New York 20, New York, or 100 Bush Street, San Francisco 6, California. In Canada: Shell Oil Company of Canada, Limited, 505 University Avenue, Toronto 2, Ontario.

SHELL DARINA GREASE

the multi-purpose, high-temperature grease

SHELL

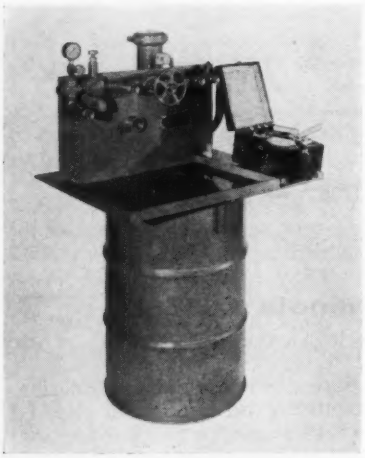
NEW PRODUCTS

(*Cont. from p. 344*)

result in virtually frictionless running. Because of its pliability, it compensates for inequalities which may exist in worn or out-of-round shafts. It can be used in: valves, stuffing boxes, pistons, cylinders, valve stems, centrifugal or rotary shafts in such equipment as: steam engines, pumps, traction engines, air compressors and others. Further information on Lonsor packing may be obtained from Newage Industries, Inc., 222 York Rd., Jenkintown, Pa.

TEST BENCH USED TO CHECK HYDRAULIC SYSTEM

A low cost hydraulic system test bench which can be used to check repaired parts in the shop and trouble-shoot operating conditions in the field is reportedly slashing costly downtime of construction, road building, mining and heavy industrial equipment. Designed by Schroeder Brothers, McKees Rocks, Pa., manufacturers of hydraulic, electrical and pneumatic equipment, this double-duty "Barrel Bench" is supplied either as a built-up unit or in component parts for customer assembly. The bench consists



of a work table equipped with strainers, suction filter, micronic filters and drains, with which a standard 55-gallon drum can be used as a reservoir. Instrumentation is provided by a portable circuit tester measuring flow, pressure and temperature. Equipped with quick disconnects this tester may be removed from the bench and connected into the hydraulic system of the faulty equipment to pin-point defective pumps, valves or cylinders before any parts are removed. A pump drive unit, driven by either electric motor or internal combustion engine, completes the bench test assembly.

MECHANICAL SEALS

A new series of mechanical seals have been developed for installation on sealed vessel agitator shafts. Known as Mechanipak seals, they are completely self-contained in a single unit for simple, quick installation. The units are designed to prevent agitator shaft leakage at pressures up to 3,000 psi and to withstand temperatures in excess of 700F, even in corrosive environments. The seals are currently available in sizes to fit any shaft. Further information on Mechanipak high pressure, high temperature mechanical seals can be obtained by writing to the Garlock Packing Co., 437 Main St., Palmyra, N. Y.

SHIELDING PROBLEM SOLVED

Design engineers at New Hampshire Ball Bearings, Inc., research center reportedly have taken a step forward in solving a troublesome shielding problem that has confronted the miniature bearing industry for some time. A slight design change of the bearing's inner ring resulted in an effective shield that is claimed to reduce by as much as 70 per cent the size of dirt particles which can get into the bearings, according to the company's engineers. Also important to long life of bearings, the simplified design reportedly leaves no corners where dirt and dust can collect to cause drag between shield and inner ring. The full thickness on the side of the inner ring provides a broader reference surface for the mounting.

REUSABLE CARTRIDGE FILTER

A new type of filter recently introduced by T. Shriver & Company, Inc., Harrison, N. J., reportedly combines the ease of operation of the cartridge type filter with the low cost operation of conventional precoat filters. Designed primarily for the removal of small quantities of solids from low viscosity liquids and gases, the filter utilizes a formed-in-place cartridge of cellulose or synthetic fibers on a permanent base. By a combination of especially engineered support and controlled grinding of the fibers, it is possible to produce a formed-in-place cartridge that does not drop off the support when the flow through the filter is stopped. When the cartridge has become plugged with solids, manual or automatic means are provided for removing the solids from the base and washing the solids into a small scavenger unit. In the case of liquids, the solids may be semi-dried to reduce liquid loss. Available in sizes with filtering areas from one to several hundred square feet. Constructed in all of the commonly used materials. This filter can be readily engineered to a specific operation.

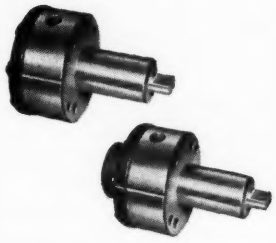
SYNTHETIC OIL PROTECTS OVER WIDE TEMPERATURE RANGE

A chemical company is now marketing a synthetic instrument oil which offers a significant increase in temperature range and lubricant life over customary petroleum-base lubricants. Anderol L-281 Instrument Oil is a medium viscosity diester oil engineered specifically for use in precision instruments. Physical characteristics of the synthetic lubricant reportedly includes an evaporation rate so low that it remains fluid up to 100 times longer than ordinary instrument oils. The temperature range of this new lubricant is claimed to be the widest possible . . . from —75F to 350F. Compatible with ordinary lubricants, L-281 offers penetration comparable to fine penetrating oils. Like all synthetic lubricants, Anderol L-281 has remarkable oxidation stability. It is non-gumming and will not leave harmful deposits. The oil seeks out metal, clinging to the surface in a fine film that protects delicate parts from humid and salt conditions. Suggested applications for this lubricant include clocks and watches, precision bearings, pneumatic systems, hydraulic systems, electrical control boxes, electric motors, parking meters, and all types of instruments and timers. For additional information write Lehigh Chemical Co., Industrial Lubricants Div., Chestertown, Md.

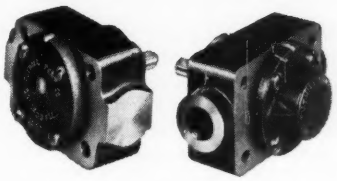
NO-DRIP ATOMIZING NOZZLE

Simplified design which utilizes one moving part means exceptional ease, speed and economy in maintenance of an adjustable-discharge atomizing nozzle, reports the Columbus Automatic Lubrication Company for spray application of lubricants, adhesives and other liquid coatings. Simple adjustment is claimed to give precise control over quantity of flow and size and shape of spray pattern. Positive shut-off at the nozzle orifice insures no-drip operation. Manifold type air and liquid connections allow nozzle assembly to be removed without disturbing nozzle mounting or hose lines. This nozzle, # 2000, is designed for operation at atomizing pressures from 1 to 100 psi. A simple mounting bracket is available to simplify installation on applications where it is practical to set the nozzle in a fixed position such as for lubrication of molds or dies for forming metals, plastics, rubber and ceramic materials. Further information on the new nozzle may be obtained by writing to CALCO, 81 E. State St., Columbus 15, Ohio.

NOW! Have Reliable Lubrication at Minimum Cost

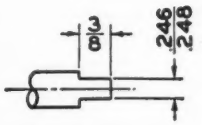


Models LF and RF
Capacities 55-170 g.p.h. at 1800 r.p.m.
Designed for flange mounting without shaft seal; with *choice* of internal or external porting. Model RF has automatic reversing feature which permits driving the pump in either direction... without changing direction of flow or port positions.

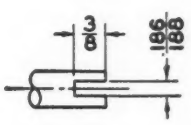


Models LFD and RFD
Capacities 60-180 g.p.h. at 1800 r.p.m.
Designed for non-directional service; for flange mounting with internal porting. Variations for external porting and/or shaft seal are shown below. Model RFD has the automatic reversing feature which permits driving the pump in either direction... without changing direction of flow or port positions.

ALTERNATE SHAFT DRIVE ENDS
For All Models



MODIFICATION "A"



MODIFICATION "B"

Tuthill "Cartridge-Type" Pumps Solve This Problem for Plant Maintenance...and Original Equipment Manufacturing

Durable—Reliable—and Available from Stock!

1. The demand for minimum cost lubrication pumps without sacrifice in performance, durability and reliability is *ideally* satisfied by the TUTHILL series of Models LF, RF, LFD and RFD *cartridge-type* pumps.

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PRODUCT LITERATURE

BOOKLET OF METAL PACKINGS

A new bulletin, dealing with the subject of metal packings for pumps, engines and compressors, has been published. The 24-page booklet, designated Bulletin AD-166, contains comprehensive data for correct selection, application and installation of metal packing and it is complete with explanatory illustrations. The bulletin is designed specifically to acquaint users with pressure temperature and other service requirements relative to the various kinds of metal packing currently available. To this end, the bulletin is divided into six subdivisions. The first section describes free-floating metal packing, taking in detail the annular solid-cup type, high pressure packing and the split-case multi-groove type. Next in order are subdivisions on metal rod packing rings, metal scraper rings, metallic or nonfloating packing and piston rings. The final section of the booklet discusses testing and service facilities available at Garlock to assist users in selecting and maintaining metal packing. Copies of Bulletin AD-166 can be obtained by writing to the Garlock Packing Co., 438 Main St., Palmyra, N. Y.

MULTI-LUBER SYSTEMS CATALOG PUBLISHED

A new catalog on its line of Multi-Luber Automatic Power Lubrication Systems for trucks, trailers, material handling equipment, farm implements and industrial machinery has been published by Lincoln Engineering Company, Division of the McNeil Machine & Engineering Company, St. Louis. Catalog No. 50 includes illustrations and specifications pertaining to air, vacuum and manually-operated Multi-Luber Systems, their various applications, methods of operation, and listings of component parts and accessories. Copies are available upon request.

BULLETIN DESCRIBES DOUBLE ROW BEARINGS

Double row ball bearings—including open, shielded and snap ring types—are described in Bulletin 111, released by a ball and bearing company. Dimension and load specifications for both light and medium series are provided together with a discussion of other application considerations. Double row bearings find most frequent use in applications requiring heavy radial loads, moderate thrust, shaft rigidity and limited housing area. Copies of four-page Bulletin 111 may be obtained by writing Advertising Department, Hoover Ball and Bearing Company, 5400 So. State Road, Ann Arbor, Michigan.

OIL SYSTEM DESCRIBED

A new bulletin illustrates and describes Trabon's compact Meter-Mist Oil Systems which are available in 12 space-saving packages, pre-wired, pre-piped and complete with all components. The bulletin shows in words and pictures just how a Meter-Mist installation works protecting bearings and gears with proper lubrication. A handy table shows how to select lubricator and reclassifier fittings. Included is information on Meter-Mist Flow Indicator Fitting which checks oil mist condition at remote bearing locations. Write for Bulletin 659, Trabon Engineering Corp., 28815 Aurora Rd., Solon, Ohio.

NEW TECHNICAL BULLETIN

"Metholene Esters for Alkylolamides" is the title of a new technical bulletin offered by Emery Industries. The procedure is given for using methyl esters of fatty acids as intermediates to produce super grade amides having active amide contents of more than 90 per cent, compared to the less than 70 per cent obtained by direct amidation of free fatty acids. Also listed are complete specifications for methyl esters, including methyl stearate, palmitate, myristate, laurate, caprate, and caprylate. The superamides prepared from properties that have led to their use in household detergents, cosmetics, shampoos, and other surfactant applications. For copy of the book, write Emery Industries, Inc., Dept. 5, Carew Tower, Cincinnati 2, Ohio, and request Technical Bulletin No. 415.

ENGINEER DISCUSSES SPRAY LUBRICATION

A technical paper, "Modern Techniques for Spray Lubricating Industrial Gearing", has been prepared by Mr. E. J. Gesdorf, Senior Application Engineer of the Farval Corporation, manufacturers of centralized lubricating equipment. Interesting application photographs and cutaway views of spray equipment are contained in the treatise. Included is a discussion on historical development of spray lubrication, followed by information on problems encountered and how these problems were solved. Copies are obtainable from The Farval Corporation, 3300 East 80th Street, Cleveland 4, Ohio.

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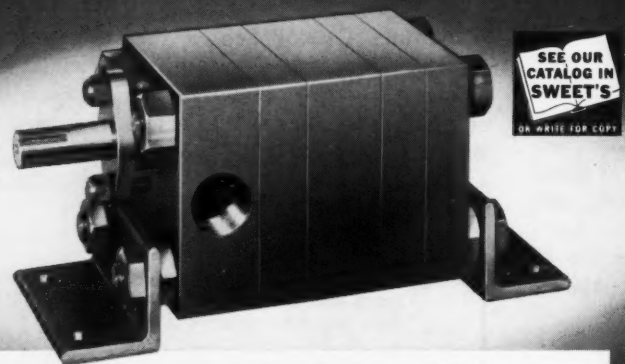

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Intensification of Research Effort Needed on Boundary Friction and Wear

Boundary friction and wear, the greatest source of industrial waste and the strongest single barrier to any substantial increases in the productivity of our machinery, is still a very complex phase of engineering.

It is a national military and industrial problem.

The slow progress in this particular phase of engineering can be attributed to the delayed recognition of the seriousness and complexity of the problem, to educational neglect, and to the refusal of engineering as a whole to accept responsibility for these deficiencies. The solution was thought to be the primary responsibility of the lubricant manufacturers.

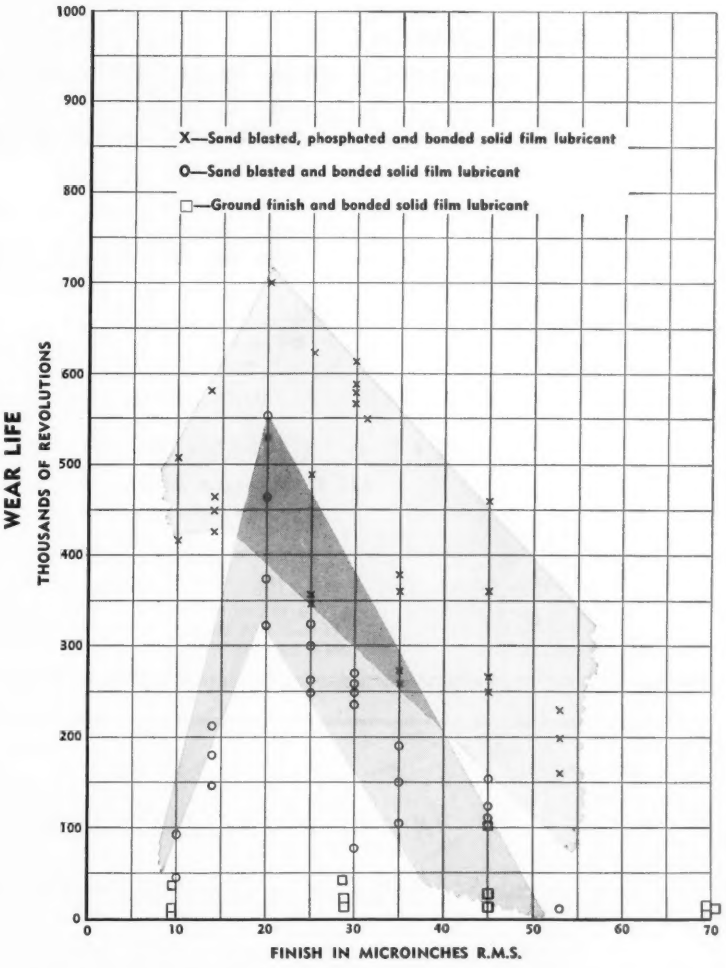
As one of these lubricant manufacturers, we take this responsibility seriously. After years of experience, we have found that the eventual elimination of boundary friction and wear as a complex will be based on *testing . . . testing . . . and more testing.* We feel that it is unrealistic to complain that the few E.P. testing machines in use do not solve the whole complex for us.

We want all the reliable testing machines we can afford and we now have 14 of one type, our Model LFW-1, in operation. Finally, we are beginning to see light after more than 100,000 testing hours on these machines. Yet, we realize that we have only begun to scratch the surface!

For example, it took 7,000 testing machine hours to plot the chart on this page which indicates the significance of surface finish and the methods used to produce it. A sharp wear-life peak appears for surfaces ground to 8 to 10 microinches r.m.s. and then sandblasted to a 20 microinches r.m.s. finish. It drops off sharply for finer or coarser finishes produced with other sizes of blasting media. Wear life is lowest for ground finishes.

Of course, surface roughness is only one of the many ingredients which make up the complexity of boundary friction and wear. A large number of these ingredients has shown up in our test data and will have to be investigated separately.

To complete the study of the effect of the surface finish alone for conditions other than those used in our tests, such as: a large variety of mating metal combinations, bearing pressures, sliding velocities, etc., an estimate of 4,000,000 testing machine hours is probably on the low side.



WEAR LIFE VERSUS SURFACE FINISH curves show the significance of surface finish and the methods used to produce it. Tests were run on Alpha Model LFW-1 testing machines. The following key indicates the testing procedures used: X shows results of samples which were ground to 8 to 10 microinches r.m.s. and then sandblasted to finish shown. After sandblasting, these samples were phosphated and then coated with a bonded solid film lubricant; ○ shows the results on samples which were ground to 8 to 10 microinches r.m.s., sandblasted to the r.m.s. finish shown and then coated with a bonded solid film lubricant; □ shows results on a ground surface coated with a bonded solid film lubricant.

About half of the energy produced in the world today is consumed by boundary friction and billions of dollars yearly are lost to boundary wear. Even if we are willing to accept these losses, we can hardly accept the condition where tremendous engineering advances are made in other fields only to be retarded by the slow progress in the field of boundary lubrication.

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Flash Point	540°F. approx.
Fire Point	570°F. approx.

Saybolt Viscosity at 210°F.	155 seconds approx.
Iodine Value (Hanus)	20.0 - 35.0
Saponification Number	100.0 - 116.0
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- Efficiency of Involute Spur Gears
  by E. E. Shipley
- Analytical Study of Surface Loading and Sliding Velocity of Automotive Hypoid Gears
  by D. L. Powell and H. R. Barton
- High Horsepower and High Torque Performance of EP Gear Lubricants
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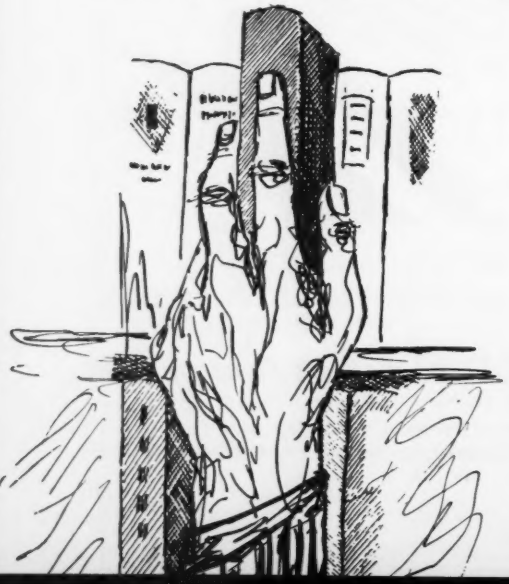

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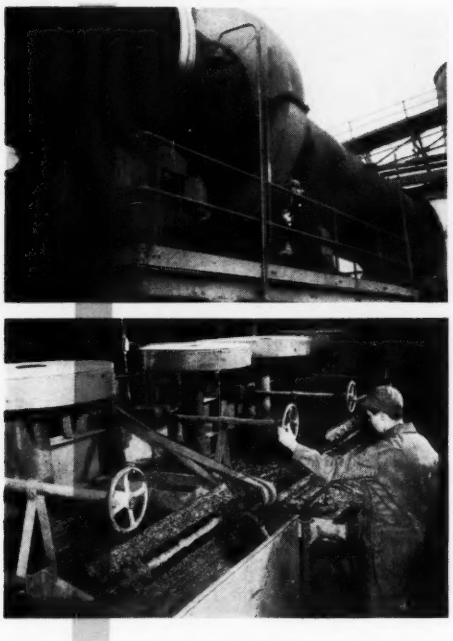

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4 common shaft sealing conditions

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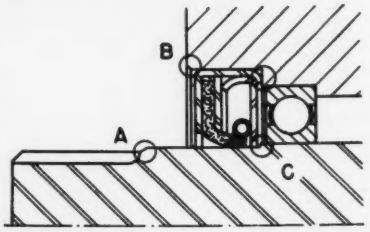
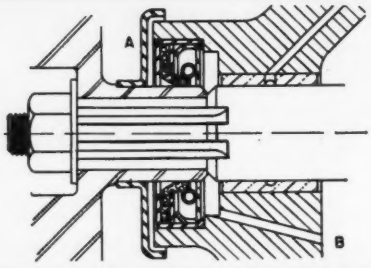
CONVENTIONAL INSTALLATION

Here a standard-design single lip seal retains lubricant and excludes normal dirt, dust and moisture. Sealing lip points in since seal's principal job is retaining oil or grease around bearing. Note that shaft is stepped and chamfered at "A" to prevent damage to sealing lip during installation. At "B", bore is chamfered to facilitate seal entry. At "C", counterboring insures accurate positioning of the seal.



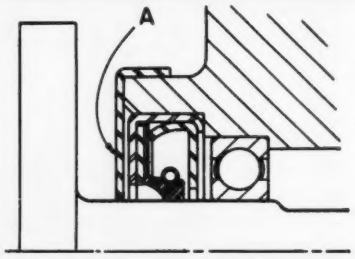
HEAVY DIRT CONDITIONS

Here is a commonly used method of protecting the seal and increasing seal life on applications subjected to extreme dirt conditions. The guard baffle at "A" is welded or swaged to the wheel hub to exclude the major portion of dirt and dust. The drain hole at "B" relieves pressure at the sealing point. In addition to the guard baffle, many manufacturers employ a dual-lip seal to insure bearing protection under extreme dirt conditions.



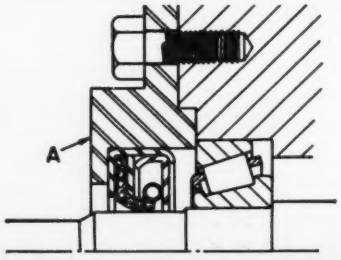
SEALING LONG, HEAVY SHAFT

Many cases of so-called "seal failure" are due solely to poor installation techniques. While today's seals are rugged, they can be rendered non-serviceable if distorted out of round, cocked in the bore, or if the sealing lip is torn. To protect the seal against such physical damage during installation involving a long shaft, a seal protector as shown at "A" may be mounted on the hub O.D.



INSUFFICIENT DEPTH TO MOUNT SEAL

Where the housing does not provide sufficient depth for counterboring, or where seal installation would be difficult or likely to damage the seal, a separate mounting member ("A") can be employed. As before, the shaft should be chamfered to prevent damage to the sealing lip during installation.



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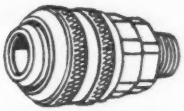

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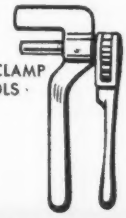

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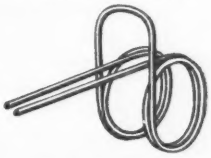

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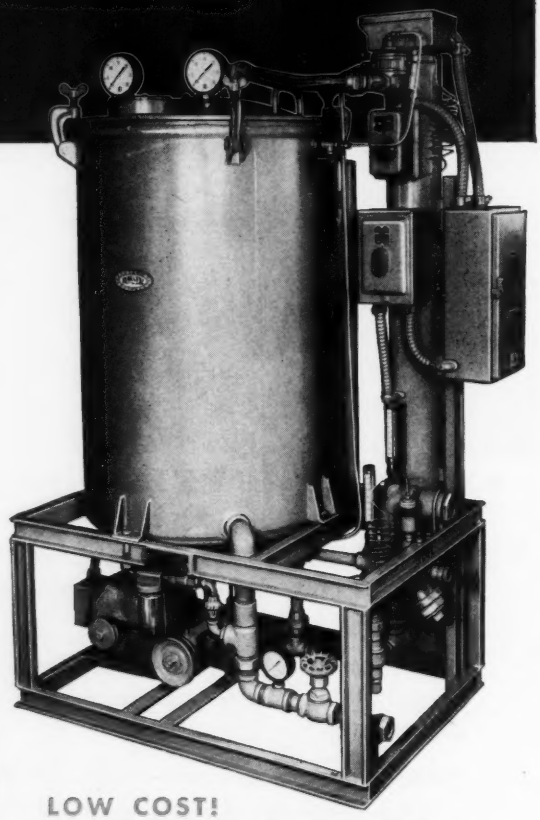

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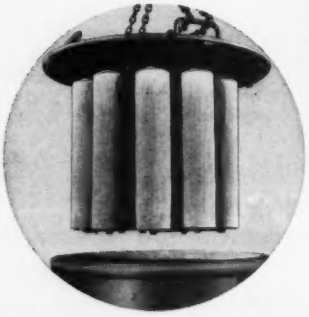

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Vol. 15, No. 9

Lubrication Engineering

Getting the material presented at technical meetings published and into the hands of the readers has always been one of the main aims of the Society. Until the facilities of the Society's Journal, LUBRICATION ENGINEERING, became considerably overtaxed, the Journal was our only regular publication medium. With the advent of ASLE Transactions, many of the publication problems which troubled us in the past have been reduced and we are now publishing more material and at an earlier date than ever before.

gear symposium papers

In this issue of LUBRICATION ENGINEERING, which is devoted to the subject of Gears and Gear Lubrication, will be found three papers presented at the ASLE Gear Symposium held in Chicago in January of this year. A paper on "The Gear Rig as an Oil Tester" also presented at the Symposium appeared in the August issue.

Five other papers presented at the Symposium are scheduled to appear in the October issue of ASLE Transactions. A list of these papers will be found on page 350 of this issue.

Publishing the Gear Symposium papers by using the combined facilities of LUBRICATION ENGINEERING and ASLE Transactions enable us to present the material to the reader much sooner than would otherwise be possible. We shall continue to try to provide the best and quickest publication possible.

John Boyd,
Editor

A Look at the Problem of Gear Lubrication

In the automotive, aviation, and marine fields as well as others, there is an ever-increasing demand for more power in minimum size packages. Since gears are usually utilized in the transmission of power, means must be found for increasing the load-carrying capacity of gears. This will require that maximum use be made of the present knowledge of gear lubrication and that the necessary research and development work be carried on to go beyond the present know-how. The purpose of this paper is to briefly review a few selected topics concerning gear lubrication that indicate the importance of finding out more about gear lubricants.

by A. Hundere

Alcor, Inc., San Antonio, Texas

IMPORTANCE OF THE LUBRICANT

Credit is given to Wilfred Lewis for first giving attention to the load-carrying capacity of gears. In 1886 he introduced the involute system of tooth profile design in addition to the well-known Lewis formula. He considered load-carrying capacity only from the standpoint of tooth breakage, treating the tooth as a loaded cantilever beam. His formula has been modified by many investigators to introduce other factors, but essentially it has remained concerned with avoiding gear failure due to tooth breakage. The introduction in 1929 of the automotive hypoid gear which would operate only on extreme pressure additive lubricants is recognized as the gear design change that started industry on the development of specialized gear lubricants. Almen (1, 2) and Blok (3, 4, 5, 6) were probably the first to recognize that gear lubricants were no less important than the gear steel itself. In 1937, Almen stated that a gear lubricant in addition to being "a lubricant in the usual accepted sense of a liquid film separating two rubbing surfaces," should also be considered as "a structural material in the sense that it is an important factor in determining the size of gears," "a chemical agent for building anti-welding films," and "a coolant." The most difficult function that a gear lubricant must perform is that of preventing excessive metal-to-metal contact in the region of maximum sliding velocity. When it is realized that the unit loading at the point of contact is as high as 400,000 psi and the sliding velocity is as high as 6,000 fpm, it is amazing that excessive wear, let alone fusion, can be avoided.

"Is gear lubrication hydrodynamic?" is a question that is continually argued among gear lubrication experts, but as yet it has not been completely answered. A number of investigators, such as Cameron (7), Gatcombe (8), and Hutt (9), have made calculations based on the hydrodynamic theory to determine the load-carrying capacity of gears. The maximum permissible load so calculated accounts for only a small part of the actual load that can be carried. Neglecting the effect of pressure on viscosity, there is about a 50:1 difference between calculated permissible values and actual operating loads in service. If allowance is made for the two-to-threefold increase in viscosity with pressure, there is still about a 20:1 difference that is not accountable by hydrodynamic calculations. This difference would be even greater if the decrease in viscosity resulting from the high increase in temperature of the contact area were not neglected. Various theories and opinions have been expressed to account for the

Presented at the 1st ASLE Gear Symposium, January 26, 1959.

wide difference between the maximum calculated hydrodynamic load and the actual load limited by scuffing. Blok (6) feels that under boundary conditions local elastic deformations of the gear tooth material may possibly alter the contact areas, thus permitting higher loads to be carried. Hutt (9) suggests that the support from the boundary film results from "the trapping of the oil in minute shallow recesses in the tooth surface and its subsequent expulsion under pressure over the brims of such recesses." Mansion (10) suggests that the oxide coating on the tooth surface may be what protects the gears from scuffing under boundary conditions. Gatcombe (8) on the other hand, attributes the difference to a vibration factor and conducted experiments to demonstrate his theory. However, he used amplitudes of the order of a thousandth of an inch. McEwen (11) has expressed the opinion that this amplitude of vibration could only be achieved in the gear teeth by torsional vibration of the system. The dynamic increment of load on the gear teeth due to such vibration would more than cancel out the gain in hydrodynamic capacity.

Regardless of which theory one chooses to accept, it is obvious that the physical and chemical properties of gear lubricants require careful consideration and investigation.

SCORING OR SCUFFING DAMAGE

The American Gear Manufacturers Association (12) lists twenty types of gear tooth failures, many of which are only refinements of others. The types of failures that are most critical for the lubricant to control are those resulting from excessive metal-to-metal contact causing injury to the tooth surface. The damage that occurs has been referred to as scoring, scuffing, abrasion, burning, rubbing, galling, abnormal wear, depending on the appearance of the tooth surface and the personal opinion of the individual involved. Scoring is the term most commonly used to define the tooth appearance that results when the tooth surface is damaged by excessive metal-to-metal contact. Kelley (13) defines scoring as a "welding and tearing action resulting from metal-to-metal contact which removes metal rapidly and continuously as long as the loads, speeds, and other operating conditions remain the same." According to Borsoff (14) the phenomenon of scoring involves melting, and the tooth appears "as if the very top layers of the metal were melted, and part of the molten metal thrown off and part smeared over the neighboring areas." Scuffing on the other hand has a broader meaning and is generally thought to include any metal-to-metal contact that damages the surface. If it is kept in mind that both scuffing and scoring mean metal-to-metal contact resulting from the load-carrying ability of the lubricant being exceeded, it makes little difference how one describes the appearance of the damaged surface.

Scuffing or scoring of gear teeth is considered to start where the tooth surface temperature is a maximum. With true involute tooth profiles this is at the tips and bottoms of the flanks. As the tooth loading is increased beyond that required for the start of scuffing, the scuffing progresses toward the pitch line.

With gears of true involute tooth profiles a certain amount of scuffing can be tolerated without becoming progressive or harmful. The wear accompanying the scuffing reduces the load on the scuffed area which, in turn, reduces the tendency for scuffing. The redistribution of load so obtained will progress until the scuffing ceases and heals over, providing the scuffing is limited to the region of double tooth contact, and the tooth surface is not too badly damaged. To prevent this type of scuffing, highly loaded gears are made with modified tooth profiles (tip relief) in an attempt to hold the scuffing tendency constant over the entire tooth surface.

Since fusion and welding occur between the surface asperities of the contacting teeth at the instant of scuffing, it is probable that the tips of these asperities reach a very high instantaneous temperature. Blok (3) recognized this and in 1937 developed a theoretical formula for the instantaneous surface temperature that he called "temperature flash." His calculations were based upon the conversion of friction energy into heat energy.

Blok assumed that straight mineral oils have a critical temperature at which they fail, dependent only on viscosity grade. He made thermo-electric temperature measurements on spur gears utilizing a planetary gear machine. With this technique the material used for the mating gears are each sufficiently different metals so that any contact between the two gears produces in effect a thermocouple junction. Blok obtained sufficient data to prove the proportionality of his temperature formula. The possibility of using the thermo-electric technique for obtaining a non-destructive method for comparing the load-carrying ability of lubricants seems a worthwhile subject for investigation.

GEAR TOOTH PITTING

Another type of tooth surface damage that the lubricant influences is that of pitting, or surface fatigue. The pits consist of areas where particles have broken away from the surface. Pitting takes place independently of scuffing and occurs in the area of maximum stress, which is the pitch line. This, incidentally, is the area of minimum scuffing tendency. Very little work has been done on the effect of lubricants on pitting; consequently, there is considerable question as to the degree that lubricants influence pitting. Way (15) has shown experimentally that with pure rolling, pitting occurs only in the presence of a lubricant. It is believed that a lubricant of increased viscosity reduces pitting by providing an increased cushioning effect. Hutt (9) has presented data from the IAE machine showing a 190 per cent increase in fatigue life with a viscosity change from 90 to 140 centistokes at 158F. He also found that chlorine and sulfur EP additives increased the tendency for pitting. Recent data obtained from the Ryder gear machine

(*Cont. on p. 371*)

Recent Developments in the Lubrication of Heavy

Effective lubrication of heavy duty industrial gearing often presents problems requiring special considerations beyond those normally applied in the selection of lubricants on the basis of their properties and characteristics. Laboratory testing of such gears at rated load and speed has provided useful information on the performance of various types of lubricants and their application.

Endurance of lubricant film on gear teeth was investigated to determine frequency of application and quantity required when intermittent lubrication methods are employed. Differences in the characteristics of various types of lubricants in this respect are reported.

Requirements for number and location of spray nozzles to obtain effective and adequate lubricant coverage were investigated.

General lubrication recommendations are presented based on test results and field performance data.

The properties and characteristics required for lubrication of the loaded contacting surfaces of gear teeth and the theoretical aspects of gear lubrication have been the subjects of numerous papers and discussions. Considerable reference information is provided in some of this technical literature, (1) (2) (3) (4).

In actual practice the effective lubrication of tooth surfaces on heavy duty industrial gearing has often presented problems requiring considerations beyond those normally applied in the selection of gear lubricants on the basis of their properties and characteristics. Observations and inspections made on the performance and operation of so-called "open gearing" driving grinding mills in the mining and cement industry have indicated that such gearing in many cases was not effectively lubricated.

In discussing the attendant problems with the users of this equipment, the operating and maintenance personnel generally ask these questions regarding improved lubrication on their gearing: 1. "What type of lubricant should be used?" 2. "How much lubricant should be applied?" 3. "How often should it be applied?" Experience through the years has provided some general answers to these questions, but the observations and data on actual applications indicated that the basic answers to questions regarding more effective lubrication of gear teeth required laboratory controlled tests on mill gearing at rated speeds and tooth pressures.

This paper deals with the test program undertaken to study the problems associated with "open gear" lubrication and those developments in the lubrication of heavy duty gearing which resulted from the tests and a careful analysis of gear drives using pressure, splash and intermittent application of lubricants.

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TESTING FACILITIES AND EQUIPMENT

The testing of a gear drive such as is used on a grinding mill under rated load and speed presents a number of problems in providing the necessary facilities. This probably accounts for the fact that such load tests to investigate lubrication of gear teeth had not been undertaken. After a careful analysis of the problems involved, it was found that a special lapping machine provided the required facilities to operate a large gear set at rated speed and tooth pressures. This machine with the test gear and lubricating system in place is shown in Fig. 1 and 2.

Fig. 1 illustrates the equipment used to load the teeth and to measure the tooth pressure and power losses. The hinged frame supporting the pinion shaft allows the pinion and gear to operate on variable center distance so that the mating teeth can be brought into tight mesh. Under tight mesh contact, pressure on the contacting profiles was developed by adjustment of the turnbuckles on the two cables attached to the hinged frame and anchored in the base of the machine. Strain gages were used to measure the exact

Duty Industrial Gearing

by G. P. Maurer
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tension in the cables required for loading the teeth at the rated pressure of 1400 pounds per inch of face. The drive shown on the right side of Fig. 1 provided the means for operating the gear set at the desired speed (15 rpm of the gear) and a torquemeter between the motor and a calibrated reduction gear unit permitted accurate measurement of power losses for determining the efficiency of the gearing.

While this method of testing loads both flanks of the gear teeth, observations and results were recorded for the normal driving or "leading" flanks of the teeth and not for the "trailing" flanks.

The specifications of the test gear set are: Pinion—21 teeth, Gear—229 teeth, 1½ DP, 23° Helix Angle—Herringbone, 25° Pressure Angle, 20 in. Gross Face, 8⅝ in. Face Width of each helix.

The lubricant spray system consisted of the following equipment:

One manually operated lubricant pump.
Four measuring halves—capacity per stroke 0.475 ounce maximum, 0.100 ounce minimum.
Four spray control valve and nozzle (external-mix type) assemblies.
Air line for spray system included a pressure gauge and an air regulating valve.

The spray nozzles were placed 9 in. from the pitch line of the gear teeth and the two nozzles for each helix were spaced 4⅝ in. apart.

SELECTION OF TEST LUBRICANTS

Heavy residual compounds have been used for "open gearing" lubrication for many years. While considerable data on their performance is available, it was felt that these compounds should be tested since their application through a spray system usually requires a diluent. As an alternate to these lubricants the heavy grades of lead naphthenates offer many desirable characteristics for lubrication of heavy duty gearing with intermittent spray systems. A variety of special lubricants and greases have also been used for lubricating the type of gearing under consideration.

Since the test program was to provide data on lubricant performance, it was decided to test these several types of lubricants. The lubricant manufacturers were contacted for their recommendations after which representative products for each type were selected.

TEST PROCEDURES

To provide factual data on quantity of lubricant and frequency of application for the different types of lubricants, it was necessary to develop a standardized procedure for the test runs.

Trial runs were made to establish the exact nature of breakdown of the lubricant film on the tooth surfaces so that the performance of each lubricant could be evaluated. The condition for establishing film breakdown was determined by operating after application of lubricant with periodic stops to check the point at which no apparent film could be wiped from the flanks of the teeth by rubbing a finger over the contacting surfaces. Continued operation after reaching this condition produced scoring and scuffing on the tooth surfaces in short periods of time indicating that the criterion for breakdown was reliable. This breakdown determines the endurance of the film on the teeth and is not necessarily a measure of a lubricant's film strength.

The test procedure for each lubricant consisted of first spraying the gear teeth until all contacting surfaces were completely covered. The gear was then operated at test speed and checked at frequent intervals for breakdown of the lubricant film on the flanks of the teeth. During each inspection for film breakdown the temperatures of the pinion and gear tooth

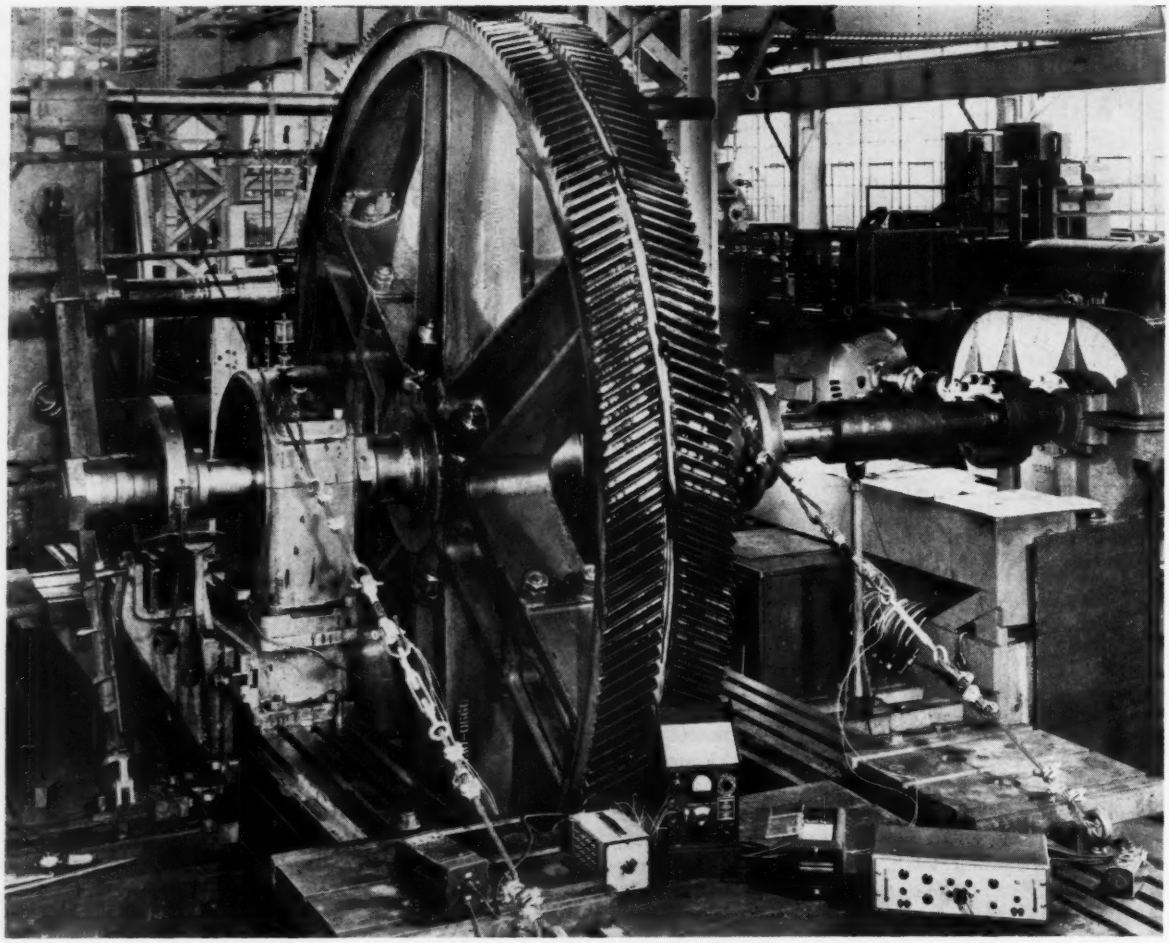

Fig. 1. Gear lubrication testing machine.

flanks were recorded. Elapsed testing time was carefully recorded to obtain total time required for initial film breakdown.

After the initial breakdown of each lubricant tested, it was re-applied in varying amounts and the breakdown time was determined for each application. It was found that applications of four ounces and two ounces provided consistent test results for comparison of characteristics and film endurance.

After the completion of the tests on each lubricant the entire pinion and gear surfaces were thoroughly cleaned with a solvent and wiped dry before starting the tests on the next lubricant.

While the foregoing outlines the general procedure for testing and recording results, it was found that each lubricant required careful and continuous observation under test in order to obtain complete pertinent data.

PERFORMANCE CHARACTERISTICS OF RESIDUAL BASE LUBRICANTS WITH EP ADDITIVES

The lubricants tested in this group had a viscosity range in undiluted form from 2100 ssu to 9000 ssu at 210 F. In diluted form the lubricants varied in viscosity from 1200 ssu to 15,000 ssu at 122 F. At ambient temperatures ranging from 70 to 90 F these lubricants with diluent as received from the manufacturer sprayed very satisfactorily through the manually operated spray system using air pressure of 60 to 80 psi.

While it is generally assumed that an increase in viscosity of a lubricant provides an increase in the endurance time of the film between applications, it was found that this was not the case for the residual compounds tested. Fig. 3 shows the time required for breakdown of the film after the initial application of lubricant and also for the four ounces used during reapplication. Plotting these values against viscosity shows no increase in film endurance for viscosities higher than 3000 ssu at 210 F for the undiluted residual base compounds.

PERFORMANCE CHARACTERISTICS OF LEAD NAPHTHENATE BASE LUBRICANTS

The lead naphthenate lubricants tested ranged in viscosity from 130 ssu to 950 ssu at 210 F. Ambient temperatures varied from 72 to 96 F. Some difficulty was experienced in pumping the lubricant having the maximum viscosity but all of the lubricants could be handled by the spray system.

Lubricants having a viscosity up to 160 ssu to 210

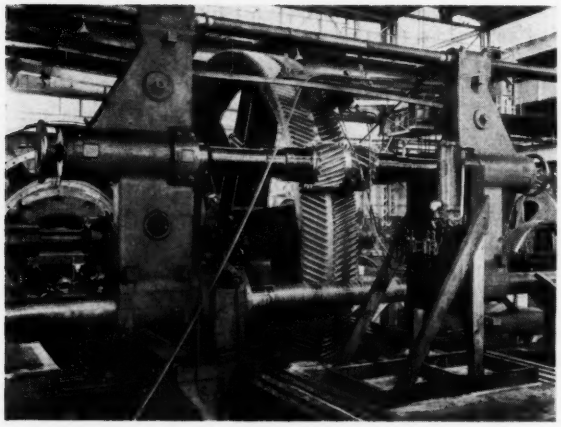

Fig. 2. Testing machine—lubricating equipment.

F required only 20 psi in pressure for atomizing the lubricant at the spray nozzle. Higher air pressures tended to vaporize the lubricants and create a mist which did not reach the gear teeth. The higher viscosity lubricants were satisfactorily applied with an air pressure of 60 psi.

The quantity of lubricant for adequate coverage on the initial application varied from 2½ to 3½ pounds which was somewhat less than that required for the residual compounds.

Some interesting and significant results were obtained on this type of lubricant with regard to the relation of viscosity to the time required for film breakdown. Fig. 4 shows the variation in time required for breakdown of the film with a change in viscosity after initial application and for re-application.

A substantial increase in film endurance is obtained with an increase in viscosity. At a viscosity of 430 ssu at 210 F the film endurance is equal to or better than that of residual compounds having a viscosity of 3000 ssu at 210 F.

Excessive throw-off of the lubricant from the pinion was experienced with lubricants having viscosities of less than 200 ssu at 210 F. The tests indicated that for intermittent spray application of lubricant on large

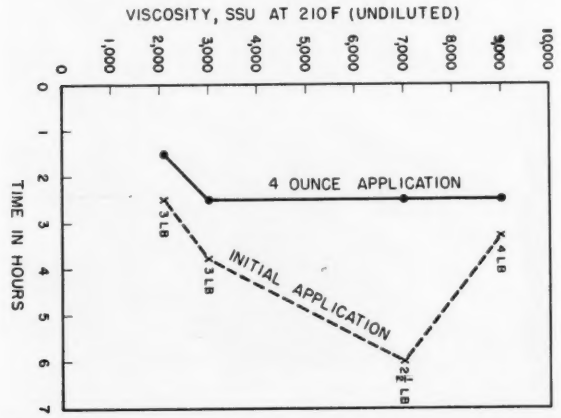

Fig. 3. Time required for breakdown of film—residual base lubricants with EP additives.

mill gearing operating at pitch line speeds of about 1000 feet per minute the viscosity of lead napthenates should be less than 500 ssu at 210 F for ambient temperatures of 40 F to 100 F.

PERFORMANCE CHARACTERISTICS OF GREASES

The greases tested had worked penetrations (degree of hardness) ranging from 295 to 355. Greases having worked penetrations of 335 to 355 were sprayed at ambient temperatures of 78 F to 84 F, but it was somewhat difficult to pump them. An air pressure of 80 psi was required for spraying. The harder greases having worked penetrations of 315 and lower could not be sprayed and required manual application with a paddle.

Initial application for complete coverage of the test gear teeth varied from one to four pounds for the several greases tested. This variation is greater than that experienced with residual base and lead naphthenate lubricants.

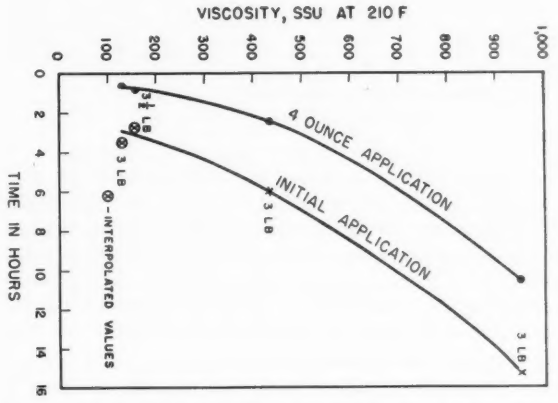

Fig. 4. Time required for breakdown of film—lead naphthenate base lubricants.

The degree of hardness of the greases was not found to be an index for endurance of the lubricant film. In this respect the greases did not have the characteristics of the residual and lead naphthenate compounds as shown in Fig. 3 and 4.

One of the fibrous greases pulled away from the tooth profile surfaces to such an extent that the fibers stood out from the top lands of the teeth beyond the outside diameter of the elements. This grease provided an effective lubricant film for only a period of 30 minutes between applications. The maximum endurance of film obtained for greases was 3¾ hours.

The spray patterns on greases were not as well defined as for the compounds and excessive splattering usually occurred. This condition can be expected from greases, but good tooth flank coverage was obtained after a short running period following application.

PERFORMANCE CHARACTERISTICS OF SPECIAL LUBRICANTS

The special lubricants offered by a number of manufacturers for gear lubrication, especially for the intermittent methods, vary considerably in their physical and chemical properties.

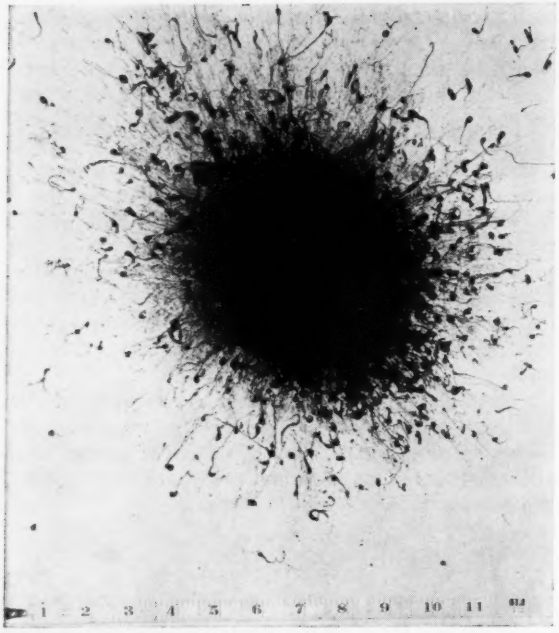

Fig. 5. Spray pattern on static surface.

Two types were tested for performance: one with a solid additive containing molybdenum disulphide and the other, an asphalt base product containing lead naphthenate and special additives. The latter product was tested in two forms; one required heating before spraying the teeth with a special applicator while the other form contained a diluent similar to that provided in residual compounds.

The performance characteristics and behavior of these lubricants under test with spray application were not as uniform as obtained with residual compounds and lead naphthenate. The lubricant with the solid additive reacted similar to the greases tested. The lubricants applied with the standard spray equipment required 60 psi air pressure to obtain the required spray pattern.

EFFECT OF WINDAGE ON SPRAY PATTERN AND COVERAGE OF LUBRICANT

One of the most important and significant performance characteristics noted in this series of tests was the effect of windage from the rotating gear. The spray pattern and the coverage of lubricant produced on the moving gear differed considerably from that produced on a static surface.

Prior to the time that this test program was undertaken, it was general practice to space spray nozzles at least 6 in. apart and also locate the end nozzles 6 in. in from the edge of the gear face. This was based on tests made on spray nozzle patterns against a static surface similar to that shown in Fig. 5 where coverage of an area in excess of 6 in. in diameter is obtained with the spray located 8 in. to 9 in. from the surface.

When directing this same spray of lubricant against the rotating test gear, the width of the spray pattern was reduced to approximately one-half of that on the static test. Fig. 6 shows this distribution of lubricant on the test gear. As a result of this phenomena the two spray nozzles for each helix were spaced 2 in. in from each edge of the face and 4⅝ in. between centers.

Observations and inspections made in the field on spray lubrication systems indicated that these systems frequently were not providing effective and adequate lubrication on the gear teeth. This was due primarily to an insufficient number of spray nozzles as determined from static spray patterns. The tests served to corroborate the field results and provided the necessary data for specifying proper nozzle spacing.

NOZZLE SPACING AND LOCATION FOR INTERMITTENT SPRAY LUBRICATION SYSTEMS

The required number of nozzles for any gear face based on the test results can be determined from the formula:

$$N = \left(\frac{F - 4}{6}\right) + 1 \qquad [1]$$

where: N is the number of nozzles expressed in the nearest whole number
F is the face width of the gear

The above formula provides the required number of nozzles so that the nozzles at each end of the manifold can be spaced from 2 in. to 2½ in. in from the ends of the gear face with remaining nozzles equally spaced at a distance between 5 in. and 7 in.

The nozzles should be mounted so that they are located a minimum of 6 in. and a maximum of 8 in. from the gear teeth and positioned so that the spray of lubricant is directed at the loaded profiles of the gear teeth (not the pinion).

Field observations made on spray systems with nozzles spaced in accordance with these specifications indicate an adequate lubricant film across the entire face of the gear teeth.

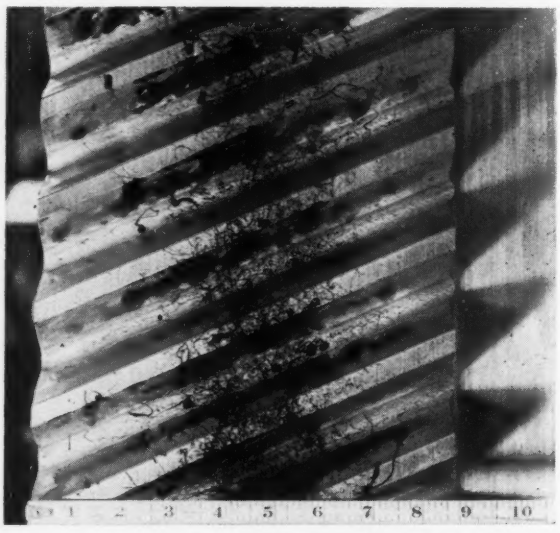

Fig. 6. Spray pattern on rotating test gear.

QUANTITY OF LUBRICANT REQUIRED FOR INTERMITTENT SPRAY SYSTEMS

The lubricant film endurance tests made with two-ounce applications indicated that this quantity after initial coverage of the teeth with lubricant provided the necessary film on the teeth for a minimum of 2½ hours between applications using lubricants suitable for this type of service. This quantity resulted in little or no loss from throw-off during application so that it represented a basic value for application recommendations. For actual performance in the field it was felt that the time between applications should be reduced to 1½ hours to provide sufficient factor for any variables which might be encountered.

Reducing this basic quantity in direct proportion to an increase in application frequency provided quantity values for an application cycle of ¼ hour generally used on automatic spray systems. This quantity was equal to 0.33 ounce or 0.0015 ounce per inch of face per foot of outside diameter of the test gear. The latter value provided the means for checking the test data against actual performance data which had been accumulated on a number of mill gear applications. The gearing which was adequately lubricated with a minimum of wasted lubricant required from 0.0007 to 0.0019 ounce per inch of face per foot of diameter on the basis of a ¼ hour application cycle.

With this data and consideration of the number of nozzles and their spacing as determined from formula [1], it was possible to determine the recommended quantities for various sizes of gearing and application cycles as shown in Table 1. These recommendations are based on providing an initial application of lubricant to cover the contacting surfaces of the teeth. Lubricating systems operated in accordance with the recommendations have provided effective lubrication on many of the major mill gear drives in the mining and cement industries. Actual operation on a given installation may require some slight changes in quantities or rate of application to obtain optimum results.

TABLE 1. RECOMMENDED QUANTITIES OF LUBRICANT

A—AUTOMATIC SPRAY SYSTEM
¼ HOUR APPLICATION

Gear Diameter in Feet	FACE WIDTH IN INCHES 8	16	24	32
10	.2 oz	.3 oz	.4 oz	.5 oz
12	.3	.3	.4	.5
14	.3	.4	.5	.6
16	.4	.5	.6	.7
18	.5	.6	.7	.8

½ HOUR APPLICATION

Gear Diameter in Feet	FACE WIDTH IN INCHES 8	16	24	32
10	.4 oz	.6 oz	.8 oz	1.0 oz
12	.6	.7	.9	1.1
14	.7	.8	1.0	1.2
16	.8	1.0	1.2	1.4
18	1.0	1.2	1.4	1.6

B—SEMI-AUTOMATIC SPRAY SYSTEM
OR HAND SPRAY GUN
1 HOUR APPLICATION

Gear Diameter in Feet	FACE WIDTH IN INCHES 8	16	24	32
10	.8 oz	1.2 oz	1.6 oz	2.0 oz
12	1.2	1.4	1.8	2.2
14	1.4	1.6	2.0	2.4
16	1.6	2.0	2.4	2.8
18	2.0	2.4	2.8	3.2

4 HOUR APPLICATION

Gear Diameter in Feet	FACE WIDTH IN INCHES 8	16	24	32
10	5.0 oz	6.0 oz	8.0 oz	10.0 oz
12	6.0	7.0	9.0	11.0
14	7.0	8.0	10.0	12.0
16	8.0	10.0	12.0	14.0
18	10.0	12.0	14.0	16.0

Note: The spraying time should be equal to the time for 1 and preferably 2 revolutions of the gear to insure complete coverage.

VISCOSITY OF LUBRICANT REQUIRED FOR INTERMITTENT APPLICATION

Intermittent application of lubricant to heavy duty gearing as used on rod mills, ball mills, paper machinery, presses, etc. requires lubricants which will adhere to the teeth at pitch line peripheral speeds up to 1200 feet per minute. The lubricants must provide a film that will resist being rubbed off the tooth profiles during the full interval of time between applications.

Not all of the lubricants tested met these requirements. However, the performance characteristics of those residual compounds and lead naphthenates tested with satisfactory results were such that the required grade of high quality lubricant can be selected on the basis of its viscosity as shown in Table 2. Here again

TABLE 2. RECOMMENDED VISCOSITY OF LUBRICANT FOR INTERMITTENT METHODS OF APPLICATION[1]

Viscosity—Saybolt Seconds Universal (SSU) at 210 F[2]			
	MECHANICAL SPRAY SYSTEMS		GRAVITY FEED OR FORCED DRIP METHOD USING EXTREME PRESSURE LUBRICANT
AMBIENT TEMP. IN DEG. F[4]	EXTREME PRESSURE LUBRICANT	RESIDUAL COMPOUND[3]	
15 to 60		1000 to 3000	
40 to 100	500 to 575	3000 to 10,000	500 to 575
70 to 125	850 to 1000	3000 to 10,000	850 to 1000

1. Feeder must be capable of handling lubricant selected.
2. Viscosities given are for lubricants in non-diluted form.
3. Diluents must be used to facilitate flow through applicators.
4. Ambient temperature is temperature in vicinity of the gears.

TABLE 3. RECOMMENDED VISCOSITY OF LUBRICANT FOR CONTINUOUS METHODS OF APPLICATION

AMBIENT TEMPERATURE IN DEGREES FAHRENHEIT[1]	CHARACTER OF OPERATION	PRESSURE LUBRICATION		SPLASH LUBRICATION		IDLER IMMERSION
		PITCH LINE VELOCITY		PITCH LINE VELOCITY		PITCH LINE VELOCITY
		UNDER 1000 FPM SSU @ 210 F	OVER 1000 FPM SSU @ 210 F	UNDER 1000 FPM SSU @ 210 F	1000 TO 2000 FPM SSU @ 210 F	UP TO 300 FPM SSU @ 210 F
15–60	Continuous Reversing	80–100[2]	60–75[2]	80–100	60–75	150–250
	or Frequent "Start Stop"	80–100[3]	60–75[3]	125–140	105–120	150–250
50–125	Continuous Reversing	125–140[2]	105–120[2]	125–140[3]	105–120[4]	400–550
	or Frequent "Start Stop"	125–140[2]	105–120	200–225[3]	150–165[4]	400–550

[1] Temperature in vicinity of the operating gears.
[2] At lower ambient temperatures, pressure lubrication systems must be equipped with suitable heating units for proper circulation of lubricant—Check with lubricant and pump suppliers.
[3] When ambient temperature remains between 90 to 125 F at all times, use a 400 to 450 SSU viscosity lubricant.
[4] When ambient temperature remains between 90 to 125 F at all times, use a 200 to 225 SSU viscosity lubricant.

the recommendations given represent those determined from test results and satisfactory performance on actual field applications.

The test results and field performance data on special compounds and certain greases indicate that these lubricants can be selected to provide proper lubrication of gearing. However, they usually cannot be specified by viscosity values and should be given individual consideration to obtain the maximum benefit from any advantages their special compounding may provide.

LUBRICATION RECOMMENDATIONS FOR CONTINUOUS METHODS OF APPLICATION

These methods of lubrication provide a continuous supply of fluid oil to the meshing gear teeth and, therefore, do not present some of the problems investigated in the tests made on the intermittent spray systems. Continuous methods are used to lubricate many heavy duty gear applications on pumps, hoists, sugar mills, and similar drives.

Applications driven by gearing lubricated by continuous methods have provided considerable data through the years on the performance of lubricants and the requirements for adequate lubrication of the tooth profiles. Also, data from lubrication tests made on large size speed reducers has provided useful information on performance of various lubricants. This data has been used to establish recommendations for the viscosity of lubricants to be used on gears furnished with continuous lubrication systems.

These methods require that the lubricant be fluid at the ambient temperature to provide proper lubrication at the start of operation of the gear drive. The lubricant is drawn from a reservoir or pump and delivered to the gear mesh either by the partially submerged rotating gear or idler, or by a direct connected or electrically driven pump. The methods are generally known as: "splash", "idler immersion" or "pressure" lubrication. The nature of the application, speed and gear arrangement usually determine the most suitable method. The gearing must be fully enclosed and the shafts adequately sealed to prevent contamination of the lubricant or leaks at the shaft.

The quantity of lubricant required for continuous methods depends upon the size of the oil reservoir, the lubrication system used, and the location of the oil level as specified by the manufacturer of the equipment.

Lighter lubricants are generally selected for gears operating at higher speeds and with pressure lubrication systems and heavier grades are used for lower speed applications. Extreme pressure lubricants are recommended except on those applications operating in high ambient humidity in which case high grade straight mineral oils should be used. Table 3 shows the recommended viscosities for various operating conditions.

CONCLUSIONS

This paper has dealt with the developments in the lubrication of heavy duty gearing based on results of recent tests and field surveys covering a variety of applications. The information presented is applicable to properly proportioned parallel shaft gears of single helical, herringbone or spur type. It is limited to gearing where the bearings for the pinion and gear shafts are lubricated separately.

The author believes that the data and recommendations meet the needs for effectively lubricating fully enclosed gear applications (for hoists, pumps, sugar mills, etc.) and semi-enclosed gear applications (for ball mills, rod mills, kilns, dryers) and many other applications operating under similar conditions. Rec-

(*Cont. on p. 371*)

A simplified laboratory method, utilizing the Falex, Timken, and Four-Ball bench testers, for evaluating the load carrying capacities of gear oils under boundary conditions is described. By the use of rating tables, the performances of gear lubricants, as indicated by these machines, are compared on an overall evaluation basis. The combined results of these tests, i.e., ratings, are more significant than the performances indicated by any one machine.

The rating system is critically examined so that the experimental errors existing in the test method are determinable. Compensation is then made in the rating system for these errors. The system is applied to a group of typical and selected commercial heavy duty gear oils and is shown to be capable of classifying these oils into their several categories.

A Laboratory Rating Method for Extreme Pressure Gear Lubricants

by A. J. De Ardo and L. B. Sargent, Jr.
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A simple, short and inexpensive laboratory method for evaluating the load carrying capacity of gear lubricants under boundary lubrication conditions is needed in industry. Laboratory apparatus which use gears as test elements most closely simulate actual industrial usage, but these are costly to acquire and to operate. Bench testers, of the Falex type, are relatively inexpensive and easy to use. These bench testers do not in themselves incorporate the action of gears if each is considered alone. However, the geometries and experimental variable, when combined, approximate gear action.

For over ten years, the combined data from Falex, Timken and Four-Ball machines have been used in these laboratories as a screening procedure (4) for the classification of heavy duty gear oils. Our experience indicates that the performance of extreme pressure gear lubricants as shown by the combined results of these tests is more significant than that indicated by any one machine. This method was critically examined in order to determine and to compensate for the experimental errors existing in the combined operation.

Presented at the 1st ASLE Gear Symposium, January, 1959.

EXPERIMENTAL

The experimental work involved in this investigation consisted of the determination of the experimental errors in our standard Falex, Timken and Four-Ball machine procedures. This was done by statistically analyzing the results of ten replicates of a MIL-L-2105 gear oil obtained from the use of these standard procedures. The following description briefly outlines the methods for use of these machines. Complete details of these tests are available as noted in the references.

A. FALEX TEST PROCEDURE

Standard steel Falex specimens are used according to the continuous loading technique test (1). A run-in period of five minutes at 500 lb load is used, after which the load is continuously increased until failure occurs as indicated by breakage of the shear pin or the inability to load faster than the rate of wear.

TABLE 1. FALEX RESULTS—MIL-L-2105 GEAR OIL SAE 90.

RUN NO.	TEST NO.:	FAILURE LOADS–lb 1	2	3	4	5	6	AVERAGE FAILURE LOAD–lb
1		2450	2650	2525	2100	2450	2550	2454
2		2800	2300	2300	2400	2150	2975	2488
3		2850	2500	2400	2250	2475	2400	2479
4		2250	2450	2300	2850	2250	2400	2417
5		2800	2300	2650	2300	2300	2300	2442
6		3350	2200	2350	2650	2300	2100	2492
7		2500	2650	2200	2050	2900	2450	2458
8		3000	2200	3000	2400	2900	2450	2658
9		2600	3100	2200	2250	2250	2400	2467
10		2200	2100	2350	2350	2200	2450	2275

Torque readings are noted at every 250 lb load increment. The load at failure is considered as the performance criterion.

B. TIMKEN TEST PROCEDURE

Standard steel blocks and bearing cups are used as test specimens. Ten minute runs are made at various load levels; these levels are increased until failure occurs which is indicated by obvious scoring of the test specimens (2). The maximum load without failure and the unit pressures existing at this maximum safe load are considered as the performance criteria.

C. FOUR-BALL TEST PROCEDURE

Standard steel balls are used as test specimens. Runs are made at twenty load levels starting at a low level, arbitrarily chosen and using increasingly higher loads until ultimate seizure occurs (3). Each run lasts for ten seconds. Ultimate seizure is denoted by almost instantaneous complete welding of the four-ball test unit.

The scar areas formed at each load level are measured and these in conjunction with their respective loads are used to calculate the EP Value 2½ second Seizure Delay Load and the per cent Ideal Value. These three criteria along with the Weld Point are considered as the performance criteria.

TABLE 2. FOUR-BALL RESULTS—MIL-L-2105 GEAR OIL SEA 90

RUN NO.	EP VALUE	2½ SEC. SEIZURE DELAY, KG.	WELD POINT, KG.	% IDEAL
1	54.4	141	282	53
2	51.1	121	282	49
3	51.9	121	282	50
4	59.3	153	282	57
5	56.6	136	282	55
6	56.2	131	282	54
7	54.1	139	282	52
8	53.7	121	316	46
9	54.8	127	282	53
10	61.1	136	282	59

EXPERIMENTAL RESULTS

Ten replicates of a MIL-L-2105 extreme pressure gear oil were made on each of the Falex, Timken and Four-Ball machines. The experimental test results from these investigations are presented in Tables 1, 2 and 3. Statistical methods were used to analyze these data in order to determine the experimental errors involved. Standard deviation values at a 95 per cent confidence level were calculated for the various performance criteria mentioned and are presented in Table 4.

Having determined these values, rating tables were devised wherein each arbitrarily chosen level represented a significant difference from its closest neighbors. These tables are presented as Tables 5A, 5B, 5C and incorporate the results of the statistical analysis.

TABLE 3. TIMKEN RESULTS—MIL-L-2105 GEAR OIL SAE 90.

RUN NO.	OK LOAD, LB	PSI AT OK LOAD
1	55	14,900
2	60	13,300
3	60	15,400
4	50	11,900
5	50	13,600
6	50	15,700
7	55	14,100
8	50	11,100
9	50	14,800
10	50	13,200

The rating tables were devised so that increasing ratings represent increasing load carrying abilities. The final number used to signify the relative load carrying capacity of a gear lubricant is designated the "Overall Rating" and is the arithmetical sum of the numerical ratings assigned to the various performance criteria indicated in Tables 5A, 5B, 5C.

The three machines used are not rated equally, most preference being given to the Four-Ball machine and the least to the Falex. This choice is deliberate and is based on many years of experience with these machines and with field performance of heavy duty gear lubricants.

TABLE 4. PRECISION OF THE THREE MACHINE METHOD OF EVALUATING LOAD BEARING CAPACITY OF GEAR OILS.

	FOUR-BALL				TIMKEN		FALEX	
RUNS	EP	2-½ SEC. SEIZURE DELAYS, kg	WELD POINT, kg	% IDEAL	OK–lb	PSI	FAILURE LOAD–lb	OVERALL RATING
1	54.4	141	282	53	55	14,900	2454	32
2	51.1	121	282	49	60	13,300	2488	29
3	51.9	121	282	50	60	15,400	2479	31
4	59.3	153	282	57	50	11,900	2417	32
5	56.6	136	282	55	50	13,600	2442	31
6	56.2	131	282	54	50	15,700	2492	31
7	54.1	139	282	52	55	14,100	2458	31
8	53.7	121	316	46	50	11,100	2658	30
9	54.8	127	282	53	50	14,800	2467	31
10	61.1	136	282	59	50	13,200	2275	32
Average	55.3	132.6	285.4	52.8	53.0	13,800	2463	31
Standard Deviation at 95% CL	±6.9	±22.3	±22.9	±8.1	±8.9	±3,160	±228	±2.0

TABLE 5A. RATING TABLE FOR COMPARING LOAD BEARING CAPACITY CHARACTERISTICS EMPLOYING THE FOUR-BALL MACHNIE.

EP VALUE	EP VALUE RATING	2-½ SECOND SEIZURE DELAY (kg.)	2-½" SD RATING	WELD LOAD (kg.)	WELD RATING	% IDEAL EP VALUE	% IDEAL EP VALUE RATING
148–162	11	492–536	12	>794	17	84–100	6
133–147	10	447–491	11	748–794	16	67–83	5
118–132	9	402–446	10	701–747	15	50–66	4
103–117	8	357–401	9	654–700	14	33–49	3
88–102	7	312–356	8	607–653	13	16–32	2
73–87	6	267–311	7	560–606	12	0–15	1
58–72	5	222–266	6	513–559	11		
43–57	4	177–221	5	466–512	10		
28–42	3	132–176	4	419–465	9		
13–27	2	87–131	3	372–418	8		
0–12	1	42–86	2	325–371	7		
		0–41	1	278–324	6		
				231–277	5		
				184–230	4		
				137–183	3		
				90–136	2		
				43–89	1		

TABLE 5B. RATING TABLE FOR COMPARING LOAD BEARING CAPACITY CHARACTERISTICS EMPLOYING THE TIMKEN MACHINE.

TIMKEN OK LOAD (lbs.)	OK LOAD RATING	TIMKEN PSI	PSI RATING
>99	7	>60,000	11
81–99	6	53,600–60,000	10
62–80	5	47,100–53,500	9
43–61	4	40,600–47,000	8
24–42	3	34,100–40,500	7
5–23	2	27,600–34,000	6
0–4	1	21,100–27,500	5
		14,600–21,000	4
		8,100–14,500	3
		1,600–8,000	2
		0–1,500	1

TABLE 5C. RATING TABLE FOR COMPARING LOAD BEARING CAPACITY CHARACTERISTICS EMPLOYING THE FALEX MACHINE

FALEX FAILURE LOAD (lbs.)	FALEX RATING
>4000	10
3540–4000	9
3070–3530	8
2600–3060	7
2130–2590	6
1660–2120	5
1190–1650	4
720–1180	3
250–710	2
0–240	1

TABLE 6. OVERALL RESULTS OF TYPICAL GEAR OILS.

LUBRICANT NO.	FALEX (lb)	TIMKEN OK (lb)	TIMKEN PSI	FOUR-BALL EP	FOUR-BALL 2-½" SD (kg.)	FOUR-BALL WELD PT. (kg.)	FOUR-BALL % IDEAL	TYPE	OVERALL RATING
1	610	45	16,000	38	83	224	41	Lead soap	22
2	2460	45	13,500	38	87	224	41	Lead-sulfur	26
3	2640	55	32,000	50	92	282	42	Lead-sulfur chlorine	33
4	2960	25	12,700	49	115	251	47	Sulfur-chlorine	28
5	620	8	9,300	18	60	112	40	Straight mineral	16
6	>4000	65	21,400	63	150	282	60	Sulfur-chlorine Army Spec. 2-105B	39
7	730	40	13,200	41	68	282	40	Lead soap	23

Several gear oils previously evaluated in these laboratories, representing a wide spread in load carrying characteristics, were re-rated using this new technique with the results shown in Table 6. The results of some recent evaluations of several MIL-L-2105 and API-GL4 gear oils were rated and are presented as Table 7.

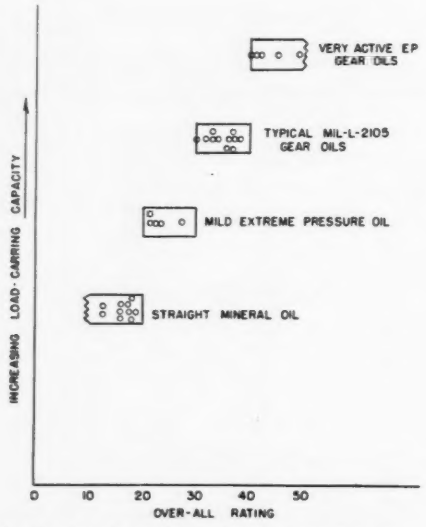

Fig. 1. Classification of gear lubes based on overall rating.

The precision of this new method (Table 4) indicates that the standard deviation at 95 per cent confidence level is 2 in the "Overall Rating." Therefore, judgment passed on the performance of any gear lubricant based on this method of determination must be made with this tolerance in mind. This method permits the classification of gear lubricants into the following groups:

Lubricant Type	*Overall Rating*
Straight mineral oil	10-20
Mild EP	20-30
Typical MIL-L-2105	30-40
Very Active EP	>40

The correlation of this grouping with some experimental results is shown in Fig. 1.

CONCLUSIONS

A method of screening extreme pressure gear lubricants in the laboratory according to their load carrying capacities under boundary lubrication conditions, as shown by tests with the Falex, Timken and Four-Ball machines, was devised. This method incorporates the experimental error involved in each machine and accounts for these errors in the final rating system.

TABLE 7. OVERALL RESULTS OF SELECTED GEAR OILS.

LUBRICANT NO.	FALEX (lb.)	TIMKEN OK (lb.)	TIMKEN PSI	FOUR-BALL EP	FOUR-BALL 2-½" SD (kg.)	FOUR-BALL WELD PT. (kg.)	FOUR-BALL % IDEAL	TYPE	OVERALL RATING
8	3875	35	17,000	64	134	398	44	MIL-L-2105	36
9	2942	20	13,250	59	134	316	50	API-GL-4	31
10	3992	30	17,200	69	154	398	47	"	36
11	3783	30	17,200	63	136	355	48	"	35
12	2942	20	14,100	75	152	398	51	"	34
13	2908	20	13,200	68	140	355	52	"	32
14	3550	30	15,500	78	136	398	53	"	38
15	4000	20	7,100	116	106	794	74	Lead-sulfur	47
16	4000	65	27,200	70	94	398	47	MIL-L-2105	39
17	3210	65	28,550	63	172	282	60	"	38
18	2640	48	22,700	51	115	249	52	—	32
19	800	5	4,800	18	48	95	52	—	17
20	2463	53	13,800	55	133	285	53	MIL-L-2105	31
21	2342	30	18,500	71	151	447	48	API-GL-4	34
22	2517	30	19,700	88	210	398	60	"	37
23	1975	45	13,000	49	83	316	42	—	28

A LABORATORY RATING METHOD OF EXTREME PRESSURE GEAR LUBRICANTS

Based on much laboratory data and field experience, this rating system is useful for screening new heavy duty gear lubricants and also for determining the load carrying capabilities of gear lubricants in service.

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A LOOK AT THE PROBLEM OF GEAR LUBRICATION

(*Cont. from p. 359*)

using 14½ pressure angle gears showed essentially no change in the pitting tendency when the viscosity was increased from 3 to 20 centistokes (16). It is the writer's opinion that it is not the viscosity as measured by the normal viscosimeter that controls the effect of viscosity on surface fatigue. Also, there are extremely important lubricant factors besides viscosity such as chemical or corrosive effects that influence pitting. Cordiano has shown a 20 to 1 change in fatigue life of ball bearings when operating on widely different fluids of essentially the same viscosity as measured by the standard viscosimeter tube.

CONCLUSION

It can be said that much yet remains to be learned about gear lubrication and lubricants and that young researchers need not worry about running out of work. It is hoped that future research will be directed toward learning sufficiently about the mechanism of gear lubrication so that the service performance of lubricants can be accurately predicted by simple laboratory tests.

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RECENT DEVELOPMENTS IN THE LUBRICATION OF HEAVY DUTY INDUSTRIAL GEARING

(*Cont. from p. 266*)

ommendations for the lubrication of such gearing nave been reduced to their simplest form commensurate with the requirements for effective and adequate lubrication. The information presented enables lubricant suppliers to select and provide the user with the best lubricant to suit the application.

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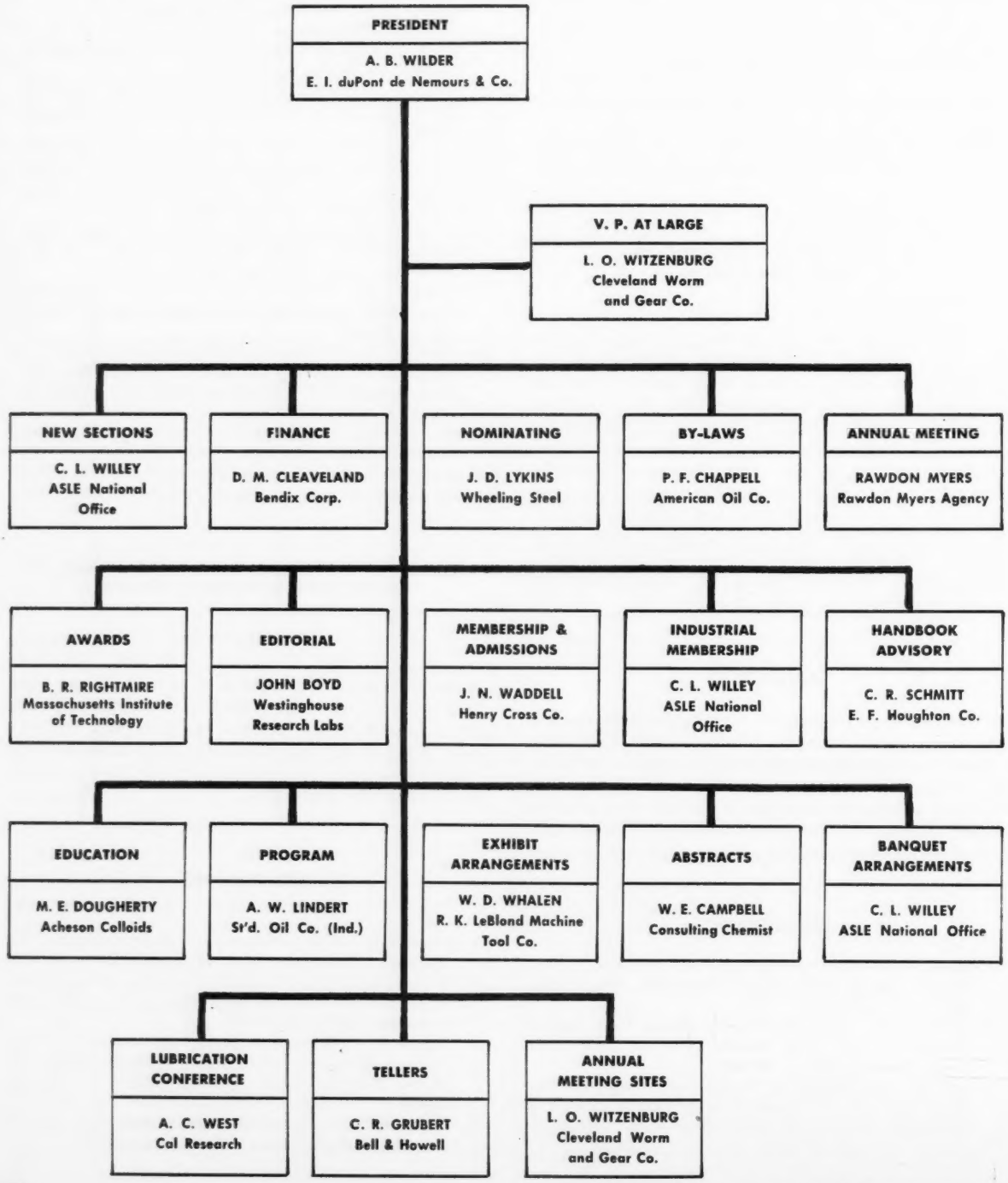
A S L E

ADMINISTRATIVE COMMITTEES AND CHAIRMEN
APRIL 1959—APRIL 1960



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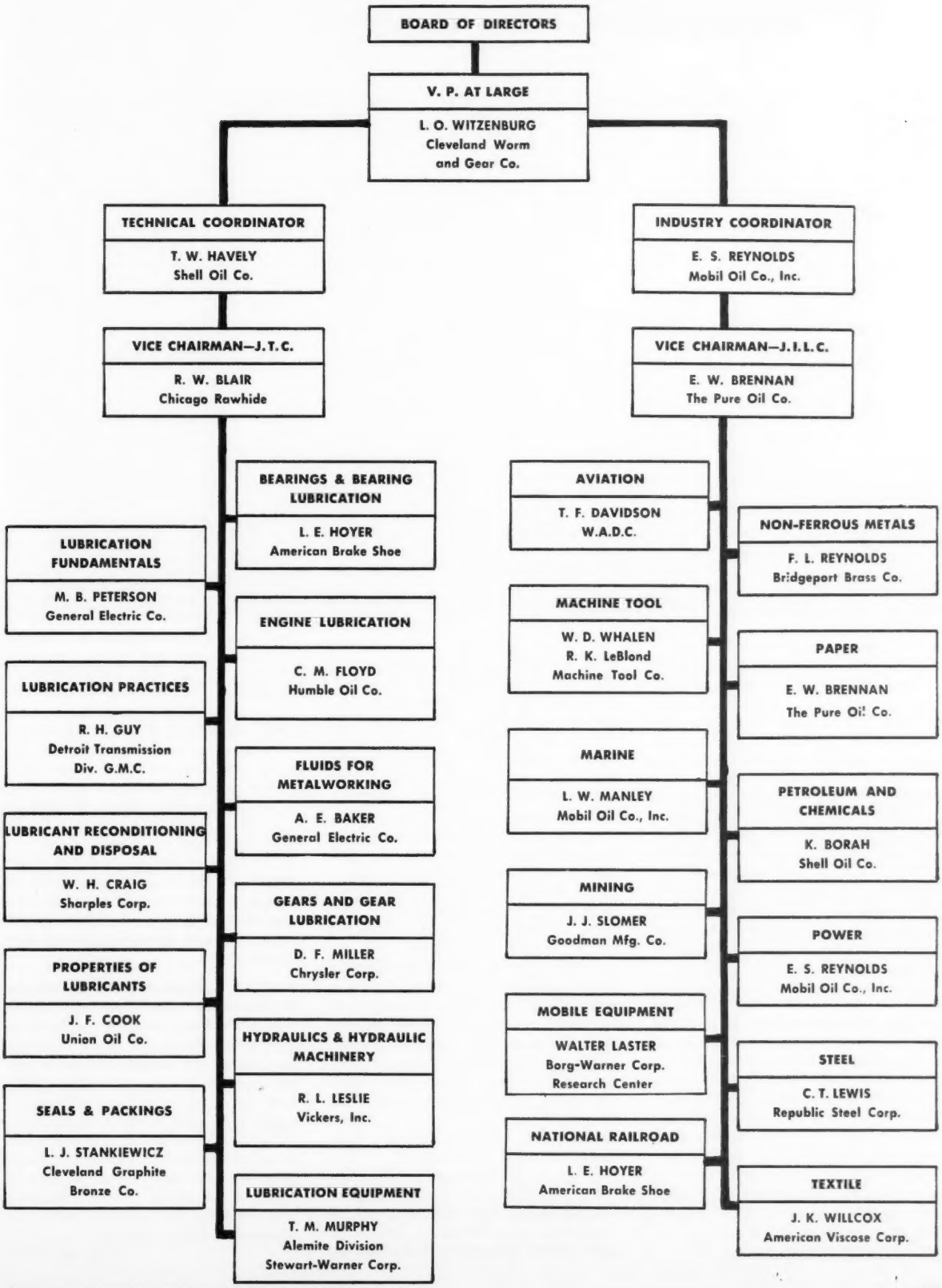

Patent Abstracts

Compiled by Ann Burchick
Aluminum Co. of America

Lithium Greases Containing Excess Lithium Hydroxide, Patent #2,883,342 (L. W. Sproule, L. F. King and W. C. Pattenden, assignors to Esso Research & Engineering Co.) A lubricating grease composition comprising a major proportion of a mineral lubricating oil, a minor grease-making proportion of a lithium soap of hydroxy stearic acid and in the range of 1.0 to 2.0 wt per cent free lithium hydroxide.

Rust Inhibitor Composition, Patent #2,884,379 (H. W. Rudel and M. Gargisa, assignors to Esso Research & Engineering Co.) A rust-inhibiting composition of matter comprising a major proportion of a mineral oil containing about 0.005 to about 0.20 weight per cent, based on the weight of the total composition, of a rust preventive consisting essentially of an isomeric mixture of acids.

Coating Composition Comprising Paraffin Wax, Microcrystalline Wax and Petroleum Distillate Oil, Patent #2,885,341 (J. D. Tench and E. B. Ewan, assignors to Sun Oil Co.) A wax composition consisting essentially of a hydrocarbon paraffin wax derived from petroleum and having a melting point of 125F to 132F, a tensile strength at 40F of from 275 to 325 psi, the tensile strength at 40F being at least 25 psi higher than the tensile strength at 70F, from about 3 per cent to 4 per cent by weight of a microcrystalline wax derived from petroleum and having a melting point of from 185F to 200F, a viscosity of from 81 to 89 sus at 210F, a penetration of from 30 to 65 at 160F, and a penetration of not above 5 at 77F, and from about 0.3 to 0.5 per cent by weight of a petroleum distillate oil having an API gravity at 60F of from 27.5 to 33, a viscosity at 100F of from 100 to 650 sus and a pour point of 0F maximum.

Process for Refining Lubricating Oils with an Alkylene Oxide and an Adsorbent, Patent #2,885,353 (W. J. Sandner and W. L. Fierce, assignors to The Pure Oil Co.) The method of reducing the organic acidity of mineral lubricating oil comprising contacting said oil at temperatures of about 350-625F simultaneously with solid adsorptive clay and alkylene oxide volatile at the contacting temperature, the clay and alkylene oxide being used in such amounts as to synergistically effect reduction of the acid number, said contacting being carried out in a substantially moisture-free, non-oxidizing atmosphere for a period of time sufficient to effect a substantial reduction in acidity of the oil.

Lubricant Compositions, Patent #2,885,361 (E. K. Fields, assignor to Standard Oil Co.) A lubricating oil composition comprising a major proportion of a lubricating oil base and between about 0.001 and 20 per cent of an additive prepared by neutralizing a mixture of an oil-insoluble amino carboxylic acid and a phosphorus sulfide-hydrocarbon reaction product with at least one basic reagent selected from the group consisting of basic alkali and alkaline earth metal compounds, said mixture containing between 0.5 and 20 parts of the amino carboxylic acid per 100 parts by weight of the phosphorus sulfide-hydrocarbon reaction product.

Coating Composition and Process, Patent #2,885,295 (H. A. McCord, assignor to MLLK Corp.) An aqueous coating composition consisting essentially of from about 1 to 90 per cent by volume of a water soluble soap, from about 1 to 90 per cent by volume of a water insoluble soap, sulfur in an amount not over 10 per cent by volume, and an inert filler in an amount not over 80 per cent by volume.

Coating Composition Comprising Paraffin Wax and Microcrystalline Wax, Patent #2,885,340 (J. D. Tench, assignor to Sun Oil Co.) A wax composition consisting essentially of a hydrocarbon paraffin wax derived from petroleum and having a melting point of from 125F to 132F, a tensile strength at 40F of from 275 psi to 325 psi, the tensile strength at 40F being at least 25 psi higher than the tensile strength at 70F, and from 1.4 per cent to 2.6 per cent by weight of a microcrystalline wax derived from petroleum and having a melting point of from 185F to 200F, a viscosity of from 81 to 89 sus at 210F, a refractive index (n_D^{212}) of from 1.435 to 1.438, a penetration of from 30 to 65 at 160F, and a penetration of not above 5 at 77F.

Non-Flammable Corrosion Preventive Compositions, Patent #2,828,213 (L. L. Neff and Wm. L. Wasley, assignors to Union Oil Co. of California) A non-flammable rust preventive composition suitable for application to ferrous metal surfaces, to form a solid, non-brittle, non-tacky adherent coating thereon, which comprises from about 85 per cent to about 97 per cent by weight of a highly chlorinated polyphenyl, between about 0.5 per cent and about 7.5 per cent by weight of a petroleum sulfonate and between about 1.5 per cent and about 7.5 per cent by weight of a relatively high molecular weight partial ester of a polyhydric alcohol said chlorinated polyphenyl being a solid compound containing between about 50 per cent and about 70 per cent by weight of chlorine.

Textile Lubricating Compositions, Patent #2,824,832 (H. F. Leupold and C. H. Lighthipe, assignors to Nopco Chemical Co.) A textile lubricating composition which comprises a blend of (1) from about 10 per cent to about 35 per cent by weight of a blown oil selected from the group consisting of blown semi-drying oils and blown non-drying oils (2) from about 45 per cent to about 65 per cent by weight of a mineral oil having a viscosity of from about 50 to about 300 Saybolt seconds at 100F (3) from about 8 per cent to about 25 per cent by weight of a product produced by condensing at least equimolar proportions of an alkyl phenol and ethylene oxide, the alkyl groups in said alkyl phenol having from about four to about 12 carbon atoms in their carbon chain and (4) from about 3 per cent to about 17 per cent by weight of a fatty material selected from the group consisting of a fatty acid having a carbon chain length of from about eight to about 22 carbon atoms, mixtures of said fatty acids, and mixtures of said fatty acids with esters prepared by reacting a fatty acid having a carbon chain length of from about eight to about 22 carbon atoms and mixtures thereof with monohydric aliphatic alcohols having a carbon chain of from one to about five carbon atoms.

Metal-Free Lubricant Additives and Method for Preparation Thereof, Patent #2,827,434 (E. T. Wierber, assignor to Lubrizol Corp.) The process of preparing metal-free, sulfur- and chlorine-containing materials which comprises heating at 50-250C for a period of time sufficient to insure completion of the subsequent reaction a mixture of an olefinically unsaturated aliphatic compound selected from the class consisting of polymers of ethylene, propylene, butylene, amylene and hexylene, and aliphatic carboxylic esters with thionyl chloride.

(*Cont. on p. 380*)

"Since Cities Service Pacemaker 300 T-Injection molders operating perfectly."

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Advance Program for Sixth Annual ASLE-ASME JOINT LUBRICATION CONFERENCE

New York City—October 20, 21, 22, 1959.

Tuesday, October 20, 1959

SESSION I: PROPERTIES OF LUBRICANTS

Ball Room—10:00 a.m.

Chairman: H. A. Hartung, Atlantic Refining Co., Philadelphia, Pa.

Vice-Chairman: R. B. Purdy, Socony Mobil Oil Co., New York, N. Y.

"An Analytical Investigation of Visco-Elastic Effects, in the Lubrication of Rolling Contact"

R. A. Burton, Southwest Research Institute, San Antonio, Texas. ASLE Paper 59LC-1

"The Oxidation of Lubricating Oils at High Temperatures"

A. L. Williams, E. A. Oberright, Socony Mobil Oil Co., Paulsboro, N. J.

ASME Paper 59-LUB-8

"Meta-Linked Polyphenyl Ethers as High Temperature Radiation Resistant Lubricants"

C. L. Mahoney, E. R. Barnum, W. W. Kerlin, K. J. Sax, Shell Development Co., Emeryville, Cal.

ASLE Paper 59LC-2

SESSION II-A: HYDRODYNAMIC BEARINGS

Winter Garden Room—2:00 p.m.

Chairman: A.A. Raimondi, Westinghouse Research Laboratories, Pittsburgh, Pa.

Vice-Chairman: Oscar Pinkus, General Electric Co., West Lynn, Mass.

"The Calculated Journal Bearing Performance of Polymer Thickened Lubricants"

H. H. Horowitz, F. E. Steidler, Esso Research and Engineering Co., Linden, N. J.

ASLE Paper 59LC-3

"A Sommerfeld Solution for Finite Journal Bearings with Circumferential Grooves"

J. V. Fedor, Takoma Park, Md.

ASME Paper 59-LUB-4

"Bearing Oil Rings Performance"

D. C. Lemmon, General Electric Co., Lynn, Mass., *E. R. Booser,* General Electric Co., Schenectady, N. Y.

ASME Paper 59-LUB-5

"Torque Produced by Misalignment of Hydrodynamic Gas-Lubricated Bearings"

J. S. Ausman, Autonetics, Downey, Cal.

ASME Paper 59-LUB-3

SESSION II-B: METALWORKING

Ballroom—2:00 p.m.

Chairman: N. H. Cook, Massachusetts Institute of Technology, Cambridge, Mass.

Vice-Chairman: I. M. Feng, Ethyl Corp., Detroit, Mich.

"Friction Characteristics of Sliding Surfaces Undergoing Subsurface Plastic Flow"

M. C. Shaw, A. Ber, P. A. Mamin, Massachusetts Institute of Technology, Cambridge, Mass.

ASME Paper

"The Chemical Aspects of Dry-Grinding Steel with Al_2O_3 Coated Abrasives"

E. J. Duwell, W. J. MacDonald, Minnesota Mining and Manufacturing Co., St. Paul, Minn.

ASME Paper 59-LUB-6

"A Comparison of Lubricants and Coatings for Cold Extruding Titanium"

A. M. Sabroff, P. D. Frost, Battelle Memorial Institute, Columbus, Ohio.

ASLE Paper 59LC-4

"Machining Characteristics of Leaded Steel"

F. L. Bagley, Jr., R. Mennell, Watertown Arsenal, Watertown, Mass.

ASME Paper

Social Hour
Crystal Room
5:30-7:30 p.m.
Complimentary Refreshments

Wednesday, October 21, 1959

SESSION III. LUBRICATION FOR ADVANCED FLIGHT VEHICLES

Ballroom—9:00 a.m.

Chairman: E. Zeilberger, Rocket Dyne, Canoga Park, Cal.

Vice-Chairman: R. L. Johnson, National Aeronautics and Space Agency, Cleveland, Ohio.

"Sliding Characteristics of Metals at High Temperatures"

M. B. Peterson, J. J. Florek, R. E. Lee, General Electric Co., Schenectady, N. Y.

ASLE Paper 59LC-5

"Evaluation of Gear Materials Scoring at 700 F"

E. G. Jackson, C. F. Muench, E. H. Scott, General Electric Co., West Lynn, Mass.

ASLE Paper 59LC-6

"Gear Lubrication in Inert Gas Atmospheres"

B. B. Baber, G. W. Lawler,* H. R. Smith,** G. A. Beane,** P. M. Ku,** Southwest Research Institute, San Antonio, Texas,** Wright Air Development Center, Wright-Patterson Air Force Base, Ohio.

ASLE Paper 59LC-7

"A Research Program on the Investigation of Seal Materials for High Temperatures Application"

R. H. Baskey, Horizons, Inc., Cleveland, Ohio.

ASLE Paper 59LC-8

SESSION IV: SPECIAL TOPICS

Ballroom—2:00 p.m.

Chairman: A. C. West, California Research Corp., Richmond, Cal.

Vice-Chairman: E. M. Kipp, Foote Mineral Co., Berwyn, Pa.

"Hydrostatic Gas Bearings"

J. H. Laub, California Institute of Technology, Pasadena, Cal.

ASME Paper 59-LUB-1

"A General Method for Correlating Labyrinth Seal Leak-Rate Data"

F. E. Heffner, General Motors Research Laboratories, Detroit, Mich.

ASME Paper 59-LUB-7

"The Effect of Root Lubrication on the Damping of Cantilever Beams"

R. V. Klint, R. S. Owens, General Electric Company, Schenectady, N. Y.

ASLE Paper 59LC-9

Thursday, October 22, 1959

SESSION V: BASIC FRICTION AND WEAR

Ballroom—9:00 a.m.

Chairman: D. Godfrey, California Research Corp., Richmond, Cal.

Vice-Chairman: C. Goodzeit, Brookhaven National Laboratory, Upton, Long Island, N. Y.

"Frictional Characteristics of Flat Sliding Bearings"

C. O. Graves, Cincinnati Milling Machine Co., Cincinnati, Ohio.

ASME Paper

"Transition Temperatures with Four-Ball Machine"

R. S. Fein, Texaco Research Center, Beacon, N. Y.

ASLE Paper 59LC-10

"The Influence of Silicon Additions on Friction and Wear of Nickel Alloys at Temperatures to 1000 F"

D. H. Buckley, R. L. Johnson, National Aeronautics and Space Agency, Cleveland, Ohio.

ASLE Paper 59LC-11

"Distribution of an EP film on Wear Surfaces"

R. C. Wiquist, S. B. Twiss, E. H. Loeser, Chrysler Corp., Detroit, Mich.

ASLE Paper 59LC-12

SESSION VI: ROLLING CONTACT FATIGUE AND FRICTION

Ballroom—2:00 p.m.

Chairman: T. W. Morrison, SKF Industries, Philadelphia, Pa.

Vice-Chairman: E. G. Jackson, General Electric Co., West Lynn, Mass.

"Effect of Hardness, Grain Size, and Surface Finish on Rolling Contact Fatigue Life of M-50 Bearing Steel"

R. A. Baughman, General Electric Co., Evendale, Ohio.

ASME Paper

"The Importance of Spinning Friction in Thrust-Carrying Ball Bearings"

G. S. Reichenbach, Massachusetts Institute of Technology, Cambridge, Mass.

ASME Paper 59-LUB-9

"The Effect of Ball Bearing Steel Structure on Rolling Friction and Contact Plastic Deformation"

R. C. Drutowski, E. B. Mikus, General Motors Corp., Warren, Mich.

ASME Paper 59-LUB-2

"A General Theory for Elastically Constrained Ball and Radial Roller Bearings Under Arbitrary Load and Speed Conditions"

A. B. Jones, Fafnir Bearing Co., New Britain, Conn.

ASME Paper

ABSTRACTS OF ASLE PAPERS TO BE PRESENTED AT JOINT LUBRICATION CONFERENCE

AN ANALYTICAL INVESTIGATION OF VISCO-ELASTIC EFFECTS IN THE LUBRICATION OF ROLLING CONTACT, by Ralph A. Burton, 59LC-1

The pressure distribution in the lubricant film separating two cylindrical rollers has been computed for a Newtonian fluid and for a Maxwell fluid. A comparison of the results indicates that shear elasticity can have effects of first-order significance on both the magnitude and form of the pressure distribution function, reducing load carrying capacity and maximum shear stress in the film by sizeable amounts.

The equations for visco-elastic flow are discussed with emphasis on thin films. The integral form in which these equations are applied in this paper is not commonly used in lubrication theory, and offers some advantage in other bearing problems particularly when numerical computation are to be used.

META-LINKED POLYPHENYL ETHERS AS HIGH-TEMPERATURE RADIATION-RESISTANT LUBRICANTS, by C. L. Mahoney, E. R. Barnum, W. W. Kerlin and K. J. Sax, 59LC-2

Meta-linked polyphenyl ethers show considerable promise as high-temperature radiation-resistant lubricants. They are far superior to present-day products in oxidation, thermal, and radiation stability, comparing favorably with the most stable aromatics such as polyphenyls, aromatic silanes, etc. In contrast to other high-melting aromatic compounds, the ethers are liquids with superior viscosity-temperature properties and good lubrication characteristics as measured in laboratory rig tests.

Although the polyphenyl ethers were developed primarily to meet the requirements of future turbo-jet engines, their properties may also be suitable in other fields where extreme conditions of temperature and/or radiation are encountered. Suggested applications include hydraulic fluids and base stocks for greases.

THE CALCULATED JOURNAL BEARING PERFORMANCE OF POLYMER THICKENED LUBRICANTS, by H. H. Horowitz, F. E. Steidler, 59LC-3

The journal bearing performance of polymer thickened oils, whose viscosity is a function of the shearing stress, has been calculated using a digital computer. Under isothermal conditions the polymer thickened oils gave lower friction coefficients and smaller minimum clearances than mineral oils of the same low shear viscosity. However, even at the highest speeds and loads the influence of the polymer was still felt. The polymer oil did not act like the low viscosity base oil from which it was formulated. There were also small differences in the shape of the pressure distribution, the attitude angle, oil flow rate and other parameters. When the temperature rise was taken into account, assuming adiabatic conditions, the higher V.I. of the polymer oils tended to compensate for their "temporary vis-

cosity loss" so that at the highest loads the polymer oils did not give smaller minimum clearances than comparable mineral oils.

A COMPARISON OF LUBRICANTS AND COATINGS FOR COLD EXTRUDING TITANIUM, by A. M. Sabroff, P. D. Frost, 59LC-4

Investigations were conducted on a number of surface coatings and lubricants, both experimental and commercial, as part of an over-all process development program on cold extrusion of solid and hollow titanium shapes. Materials were evaluated on the basis of surface finish and extrusion pressure in cold forward extrusion of unalloyed titanium billets 1-½ inches in diameter to solid round bars 0.95 in. in diameter (60 per cent reduction).

A fluoride-phosphate chemical conversion coating proved to be most desirable from the standpoint of adherence, ease of application, and cost. The effectiveness of one coating in reducing extrusion pressure and producing a good surface finish was dependent on the lubricant used.

Various types and combinations of lubricants, including graphite, molybdenum disulfide, boron nitrate, wax, soaps, polyalkylene glycol, and sulfocholorinated mineral oil were used in conjunction with the coating. The solid films, wax, and soaps were used both alone and suspended in several resin carriers. Of the various classes of materials, the solid-film lubricants produced the best surface finishes on the extruded bars. From the standpoint of producing the best surface finish at the lowest extrusion pressure, the most effective lubricants were self-drying gum resin mixtures containing ten per cent graphite and five per cent graphite—five per cent MoS_2. With the combination of the fluoride-phosphate coating and these lubricants, hollow shapes of unalloyed titanium with surface finishes for 30 to 60 microinches were cold extruded at working pressures comparable with those for cold extruding similar steel shapes.

SLIDING CHARACTERISTICS OF METALS AT HIGH TEMPERATURES, by M. B. Peterson, J. J. Florek, R. E. Lee, 59LC-5

Abstract not available at time of publication.

EVALUATION OF GEAR MATERIALS SCORING AT 700 F, by E. G. Jackson, C. F. Muench, E. H. Scott, 59LC-6

The selection of materials for use in high Mach No. aircraft gears requires consideration of high temperature rubbing compatability. This program was designed to obtain bench test data on ten different materials for application as 700 F gear materials. Oils representing two major classes, silicone and mineral, were chosen for these tests.

A new high temperature tester patterned after the Kelley Roll Tester was designed and constructed. Scoring test up to 1200 feet per minute and up to 167,000 Maximum Hertz stress were performed on 2.5 inch rolling disc specimens. Materials included high speed tool steel and die steels, both nitrided and carburized, and flame plated titanium.

The best material in score resistance depended on which oil was used. H-12 (vacuum melted), Nitrided was best with silicone, but M1 rose from second with silicone to first with mineral oil. Except for this reversal on changing oils, the order of materials correlates fairly well with surface hardness. With through hardened materials there was no reversal.

Data are presented in the form of a calculated flash temperature parameter according to the modified Kelley-Blok equation.

GEAR LUBRICATION IN INERT GAS ATMOSPHERES, by B. B. Baber, C. W. Lawler, H. R. Smith, G. A. Beane, P.M. Ku, 59LC-7

An investigation was made of the effect of inert gas atmospheres on the gear load-carrying capacity of lubricants. The experiments were performed in two types of gear test machines, using case-hardened AMS-6260 steel test gears. It was found that two mineral oils (a solvent-extracted turbine oil base stock and a USP grade white mineral oil), as well as the same oils fortified with different extreme-pressure additives, all exhibited a decided increase in load-carrying capacity when the gears were operated in an atmosphere of nitrogen or argon instead of air. On the other hand, the response of synthetic lubricants was not found to be necessarily similar. In fact, only one of the six synthetic fluids tested showed any significant increase in load-carrying capacity when the gears were operated in a nitrogen atmosphere.

AN INVESTIGATION OF SEAL MATERIALS FOR HIGH TEMPERATURE APPLICATION, by R. H. Baskey, 59LC-8

Novel rotating seal material for potential aircraft applications at high speed and high temperatures were developed by powder metallurgy techniques. Wear tests were run without lubricant on a special machine to simulate conditions prevalent in seal applications. Several commercially available materials were also evaluated. It was found that: (1a) Two Ternary Alloys containing WB or CrN exhibited superior wear qualities against tool steel or against a nickel-chromium-iron alloy. (1b) The best wear performance was attained by sliding a commercial titanium carbide compound against itself.

THE EFFECT OF ROOT LUBRICATION ON THE DAMPING OF CANTILEVER BEAMS, by R. V. Klint, R. S. Owens, 59LC-9

Lubricating the root contact surfaces of a simple cantilever beam will increase the vibration damping of the beam. Experimental evidence is given for cantilever beams of cold-rolled steel, stainless steel, and brass, with contact surfaces dry and greased.

Soft-metal platings as alternate lubricants were used as suggested by the work of Bowden and Tabor. They are shown to produce a significant increase in the damping of cantilever beams; and while this increase is not so great as for greased surfaces, their use appears promising and worthy of further study for possible applications where grease cannot be used.

TRANSITION TEMPERATURES WITH FOUR BALL MACHINE, by R. S. Fein, 59LC-10

The seizure phenomenon in the Four Ball Wear Machine is studied using dilute solutions of stearic and capric acids in cetane and a paraffinic mineral oil. Load, sliding speed and bulk lubricant temperature are investigated. The "flash temperature" at the area of rubbing and contact is estimated using Blok's theoretical treatment.

It is shown that the estimated surface temperature corresponding to the transition from no-seizure to seizure increases with decreasing ratio of load to speed. This relationship of transition temperature to load-speed ratio for the Four Ball Machine represents an extension of previously reported transition temperature vs load-speed ratio data obtained with a pin-on-disc machine. Thus, it appears possible to quantitatively relate the condition for the onset of catastrophic wear or scoring in these two different types of bench boundary-lubrication machines provided operational variables are properly considered.

It is also shown that the transition-limited load obtained in these two bench boundary-lubrication machines qualitatively follows the same laws as wear- and score-limited loads of gear sets.

THE INFLUENCE OF SILICON ADDITIONS ON FRICTION AND WEAR OF NICKEL ALLOYS AT TEMPERATURES TO 1000 F, by D. H. Buckley, R. L. Johnson, 59LC-11

Small additions of silicon have considerable beneficial effect on performance on slider alloys. This effect has most frequently been attributed to increased hardness. The research reported was conducted to consider a hypothesis that the primary role of silicon in slider alloys is one of supporting the formation of protective surface films.

Friction and wear data were obtained at temperatures from 75 to 1000 F with a series of binary silicon-nickel alloys containing up to ten per cent silicon. Pertinent hot hardness, metallurgical and surfacefilm analysis data are included. Atmospheres used were air, mixtures of oxygen and argon, a mixture of hydrogen and nitrogen, and a halogenated methane gas lubricant.

The results show the role of silicon as a film former to be of great importance in success of silicon-containing alloys as slider materials for extreme temperatures. The range of variables studied gave friction coefficients from 0.05 to >10.00 depending on film formation tendencies. Alloys with five per cent or more silicon having a duplex structure showed the best results. Film formation resulted from surface reactions or the smearing of the softer phase from the alloys having duplex structure.

DISTRIBUTION OF AN EP FILM ON WEAR SURFACES, by R. C. Wiquist, S. B. Twiss, E. H. Loeser, 59LC-12

A new method has been developed for the determination of the distribution of EP film components on irregularly-shaped wear surfaces. It entailed the use of data from radiotracer counting, autoradiographic analysis densitometer tracings and numerical integration. The method has been applied in a study of the film formed on engine valve train parts run in an oil containing zinc dialkly dithiophosphate tagged with radioactive sulfur. The techniques is applicable to similar investigations with other additives.

The results obtained showed not only how much film was formed on wear surfaces by the additive, but it also pin-pointed areas on the mating parts, where the EP film concentrated. This type of information was not obtainable by other means. In runs made with a cam and tappet tester, the amount of sulfur film found on various valve train parts decreased in the following order: cam nose, center tappet areas and cam flat. For the same area on the tappet, activity was greater for phosphate-coated parts than for untreated parts. Preliminary results indicated that it was possible to relate contact pressure experienced by the mating surfaces fairly precisely with the amount of EP film formed.

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PATENT ABSTRACTS

(*Cont. from p. 374*)

Lubricating Oil Compositions, Patent #2,824,836 (H. M. Smith, Wm. Hoernner, and J. R. Davidson, assignors to Esso Research & Engineering Co.) A lubricating composition comprising a major proportion of a mineral lubricating oil, in the range of 0.1 to 1.5 wt per cent of a zinc dialkyl dithiophosphate having in the range of eight to 16 carbon atoms per molecule, and in the range of 0.2 to 0.7 wt per cent of a polyricinoleic acid ester of a polyethylene glycol, said glycol having a molecular weight in the range of 200 to 800 and said ester being formed from a polyricinoleic acid containing in the range of two to four molecules of self-esterified ricinoleic acid.

Soap-Salt Complex Grease Containing n-Acyl p-Aminophenol, Patent #2,824, 837 (A. J. Morway, assignor to Esso Research & Engineering Company) A lubricating grease composition which comprises a major proportion of a lubricating oil and a minor but grease thickening amount of a soap-salt complex, said complex comprising an alkaline earth metal soap of at least one high molecular weight fatty acid with an alkaline earth metal salt of a low molecular weight monocarboxylic acid containing from two to six carbon atoms, the molar ratio of said salt to said soap in said complex being between about 7.5:1 to 20:1, said lubricating grease composition containing a minor amount sufficient to eliminate crust formation and hardening.

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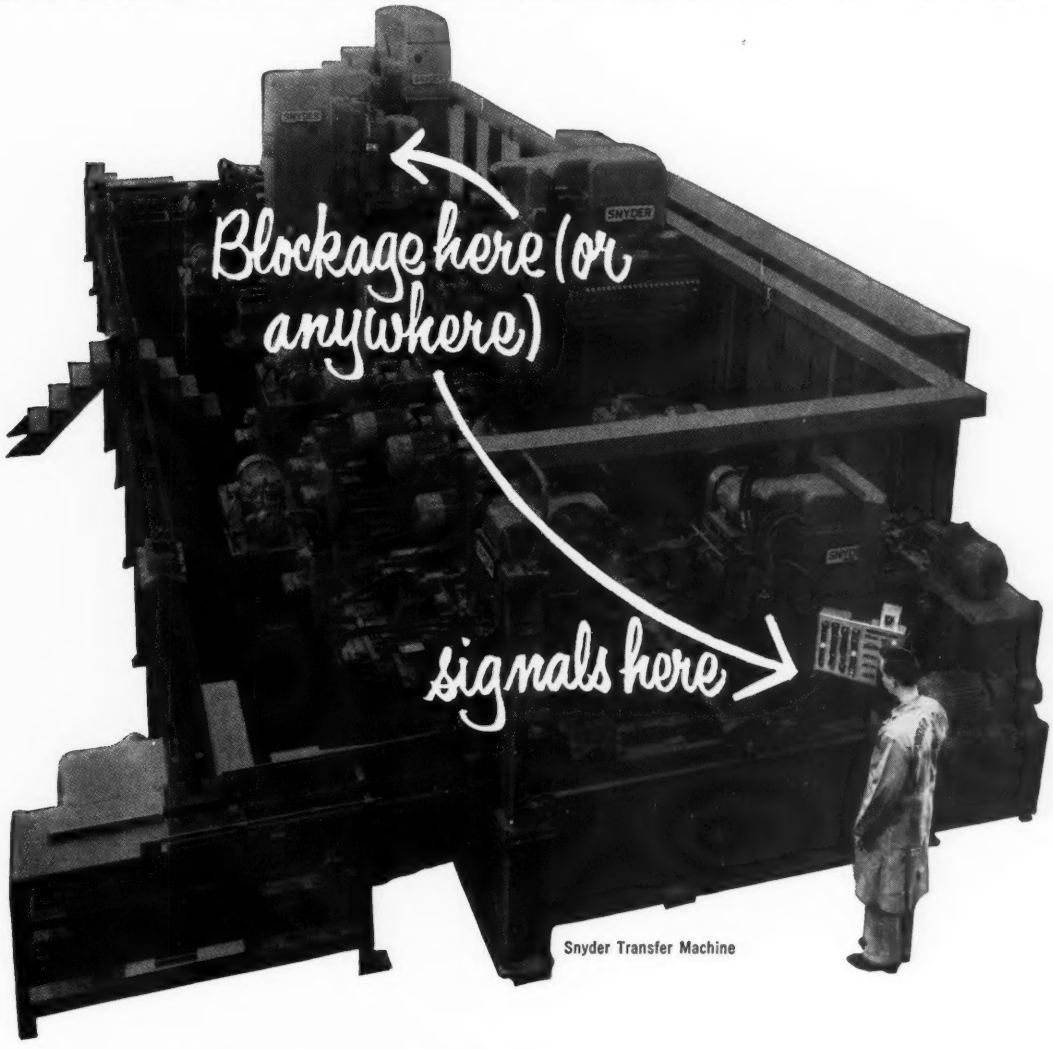

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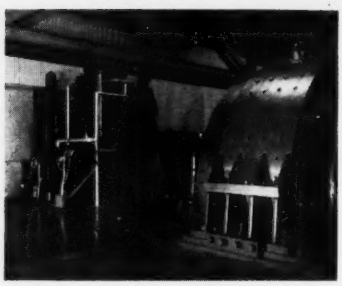

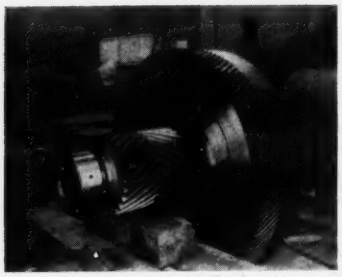

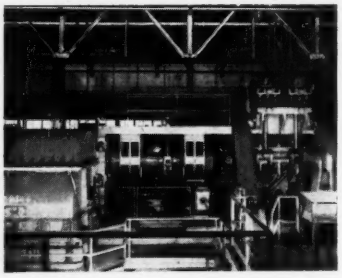

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